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THE

ELECTRICAL MAGAZINE

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PREFACE.

BEGINNING with the present number the scope of this journal has been extended, and its title amended accordingly. There is no branch of engineering into which electrical matters do not enter, and the engineering industry to-day has become as a whole the field of electrical practice. This magazine has always given precedence to the industrial and commercial as distinct from the purely scientific side of electrical work. Practice and the monetary value of work and progress are the ruling factors, and, as such, appeal to every reader; whereas, and without belittling its invaluable nature, deeply scientific research can only be followed by the few, and rarely with profit.

THE ELECTRICAL MAGAZINE AND ENGINEERING MONTHLY continues to give particular attention to the problems and progress of practical engineering: power generation by steam, gas, oil, hydraulic, or electric means, and its applications in the leading larger industries, such as collieries, mines, shipbuilding, iron and steel works, textile and timber trades, &c.; to every phase of engineering manufacture and workshop practice; also to the construction and erection of plants, installations, and public works.

Every effort is made to keep the Magazine thoroughly representative of all that is the latest and best in engineering progress, and in the forefront of all publications of this character.

June 15, 1909.

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THE PARSONS TURBINE AND ELECTRICAL WORKS.

The first practical steam turbine was built in the year 1884 by the Hon. C. A. Parsons, at which time he was a partner in the firm of Messrs. Clarke, Chapman, Parsons & Co., of Gateshead-on-Tyne. This turbine developed 10 h.p., running at 18,000 r.p.m., and was direct coupled to a dynamo. It is now in South Kensington Museum, and can be seen side by side with the early achievements of other great engineers.

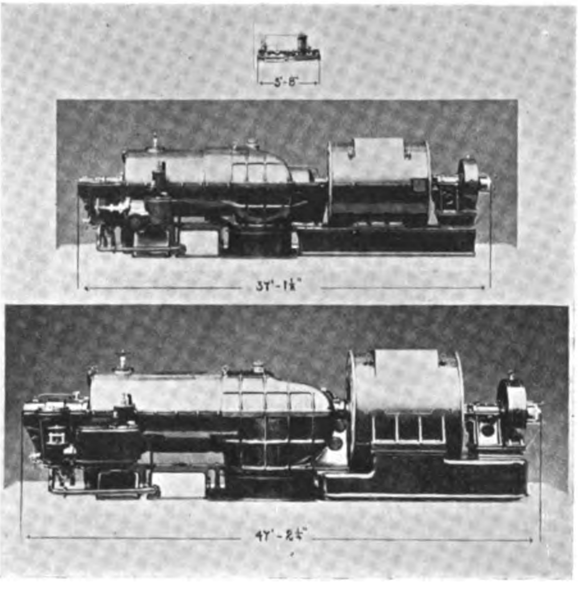


Fig. 1. Relative Size of Plants manufactured in 1884 to Present Day.

Many similar turbines coupled to dynamos were built at Gateshead, the majority of these being used for ship lighting, for which class of work they were specially suitable, principally on account of their small size and light weight. Other machines built at Gateshead were used for the generation of electricity for lighting Elswick Shipyard, Lincoln's Inn Hall, and Scotland Yard, which electric lighting installations were amongst the very earliest in the country. It is interesting to note that many of these early machines are still running, notably those originally installed at Scotland Yard.

In 1889 Mr. Parsons dissolved partnership with Messrs. Clarke, Chapman, Parsons, & Co., and started the turbine and electrical works at Heaton, near Newcastle-on-Tyne. The Heaton Works, the subject of this article, are situated at the east end of Newcastle-on-Tyne, close to the main north line of the North-Eastern Railway Company, with which they are connected. They were, of course, primarily started for the exploitation of the steam turbine and high-speed dynamo, and not for the manufacture of general plant as had been carried out at Gateshead-on-Tyne; but at the same time electrical accessories, such as searchlight projectors, arc lamps, switchgear, meters, &c., were manufactured.

It is generally known that the steam turbine has been evolved in these works from the small machines such as were manufactured previously at Gateshead to the large units which are in use at the present day in our big power stations, new designs having to be made and fresh difficulties to be overcome at every step. The dynamo also called for careful consideration in its design to enable it to be direct coupled to the steam turbine, and in its construction many new and original features had to be embodied, the majority of which had previously never been investigated. This will easily be appreciated when it is remembered that the early turbines ran ten or fifteen times faster than the ordinary reciprocating engine driven sets of the day, and, therefore, the stresses due to centrifugal force alone were of the order of from 100 to 200 times as great. It should be added that the steam consumption of these early turbines compared very favourably with that of the best reciprocating engines of that day.

The first marine steam turbine was constructed at Heaton works, as was, in fact, nearly all the machinery of the now famous "Turbinia," the high speed of which, namely, 35 knots, created much excitement at the Naval Review at Spithead in 1897.

As the Heaton Works are about two miles from the river Tyne it was thought advisable to erect another factory for the manufacture of marine steam turbines. A suitable site was chosen at Wallsend, and a company called The Parsons Marine Steam Turbine Company, Ltd., was formed, which took over the whole of the marine turbine work.

With regard to the development of Heaton Works, they, in the year 1888, covered an area of two acres, and the principal shop was only 170ft. long by 50ft. wide. It consisted of two bays in which were arranged various lathes, planing machines, &c., and the special machinery necessary for the boring of turbine cylinders and the manufacture of the blades, the latter being, perhaps, the most peculiar feature of the steam turbine. In this same shop dynamos were constructed, and the complete machine erected prior to being tested and despatched. There were also the necessary offices, pattern shop, blacksmiths' shop, testing room, &c., all adjoining the main building.

The earliest machines to be installed at the Newcastle and District Electric Lighting Company's Forth Banks Power Station were constructed in this shop. This company was formed by Mr. Parsons in conjunction with other local gentlemen in the year 1889 for the supply of electrical energy for lighting the city of Newcastle-on-Tyne.

The first machines constructed at Heaton Works were nearly all of the radial-flow type, but some machines of the parallel double-flow type—that is, with steam entering the centre of the turbine, which had right and left hand blades—had been constructed previously. The parallel double-flow type had, however, to be abandoned owing to temporary loss of the patent rights. Later on the parallel-flow type was again adopted, and has been rapidly improved and developed until it is now manufactured in sizes up to 10,000h.p. The design is now of the parallel single-flow type, a balance of end pressure being secured by means of rotating steam-balanced pistons.

The Newcastle and District Electric Lighting Company's turbine-driven lighting station having proved most successful, similar electric supply undertakings were started at Cambridge and Scarborough, Mr. Parsons also being concerned in their formation. These three pioneer companies in the adoption of steam turbines for the public supply of electrical energy, have, through their practical demonstration of the advantages and

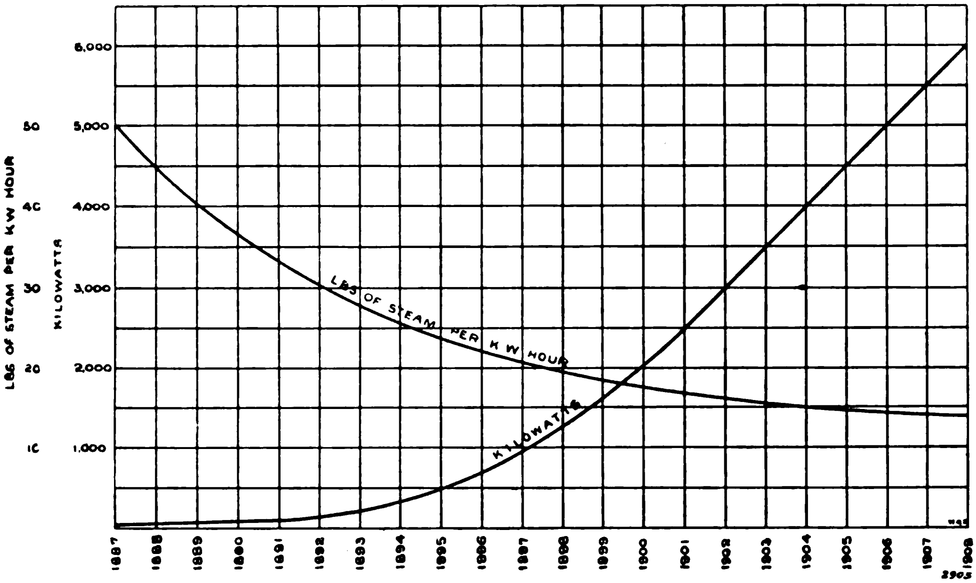


FIG. 2. CURVE SHOWING DECREASE IN STEAM CONSUMPTION AND INCREASE IN SIZE OF UNITS MANUFACTURED.

economies of this type of plant, been greatly responsible for its wonderful development.

In the year 1892 the steam turbine was first tried in conjunction with a condenser, the size of the plant being 100kw. The results obtained were so satisfactory and the increased economy so apparent that since this date probably 90 per cent. of the turbines manufactured have been of the condensing type. It may here be pointed out that the turbine particularly lends itself to working in conjunction with a condenser, as it can be so designed to utilise the steam down to the greatest possible vacuum. Through this achievement the steam turbine began to make itself felt as a severe competitor with the best reciprocating steam engine, both as regards steam economy and satisfactory working.

It may be interesting to note that in 1888 the total power of turbines at work was 4000h.p., and the largest units manufactured were of 120h.p. In 1895 this had increased, for land purposes only, to nearly 90,000h.p., with units of 500h.p., and at the present day there are over 3,000,000h.p. in use, with units of 10,000h.p. Fig. 1 shows the relative increase in size of turbines since 1884. Fig. 2 shows this in diagrammatic form as well as the decrease in steam consumption.

The Heaton Works at present cover an area of eleven acres, and comprise new erecting and machine shops on a large scale, replete with the most modern and up-to-date machinery for the manufacture of turbines and generators of all sizes. Fig. 7 shows a plan of the Heaton Works as they exist at present.

In describing the various shops, it would be as well to start with the pattern shop.

Pattern Shop.

The pattern shop is a brick building large enough to accommodate conveniently 100 men, and is 145ft. long by 40ft. wide. In it can be found every example of modern wood-working appliances. The machinery, as in all the other shops, is electrically-driven. It is interesting to note that for the sake of economy in space, the countershafting is placed under the floor.

The shop, a view of the interior of which is shown in Fig. 3, is lighted throughout by means of enclosed arc lamps.

Adjoining this building there is a large pattern store for storing and preserving the patterns of standard parts which are the most often in use.

Machine Shop.

The principal shop is a steel-framed structure erected by Sir William Arrol & Co., of Glasgow, with small brick walls for the lower portion of its sides and gables, the upper portion being covered with wood and galvanized iron. It is wholly lighted by means of a glazed roof.

The building is 400ft. long, and is comprised of two bays each 40ft. wide. One bay is devoted exclusively to machine work, and the other to fitting, erecting and assembling the various parts. Each bay is served by two electric travelling cranes, one of ten tons and the other of twenty tons capacity, manufactured by Joseph Adamson & Co., of Hyde, and also by numerous radial pillar jib cranes. Each of the electric travelling cranes is operated by three motors, which are controlled from the floor. They have a clear lift of 25ft. from floor level. At first sight, the lifting power of these cranes may seem small for a modern shop, but it must be borne in mind that the very heaviest parts of the largest turbine plants seldom exceed 20 tons in weight, and in such cases where this weight is exceeded the two cranes in each bay are used together.

The floor of the whole shop is composed of wooden blocks laid on solid concrete, and this method has proved extremely serviceable. The heating throughout is by means of exhaust steam.

Some of the larger machine-tools in the machine bay are driven by individual motors, notable examples being large planing machines which are operated by Vickers, Sons, & Maxim's electric controlling gear with reversing motors. The smaller machines are driven by two lines of overhead shafting, each operated by a 50h.p. Crompton motor driving in the middle of each shaft.

Perhaps a brief reference to some of the machine-tools in this bay may be of interest as giving an idea of the nature and extent of the operations.

The larger of the planing machines men-

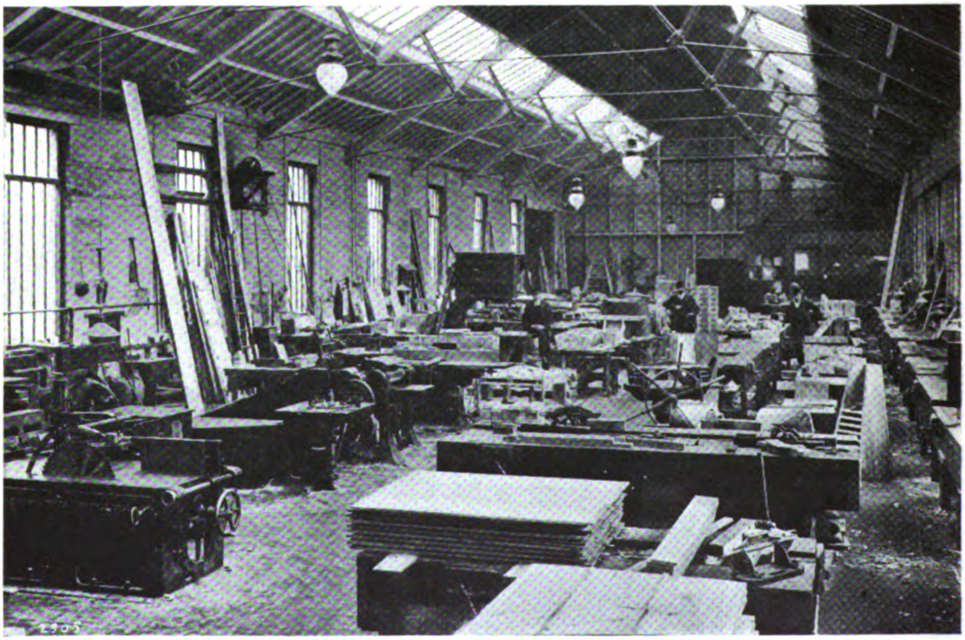


FIG. 3. GENERAL VIEW OF PATTERN SHOP.

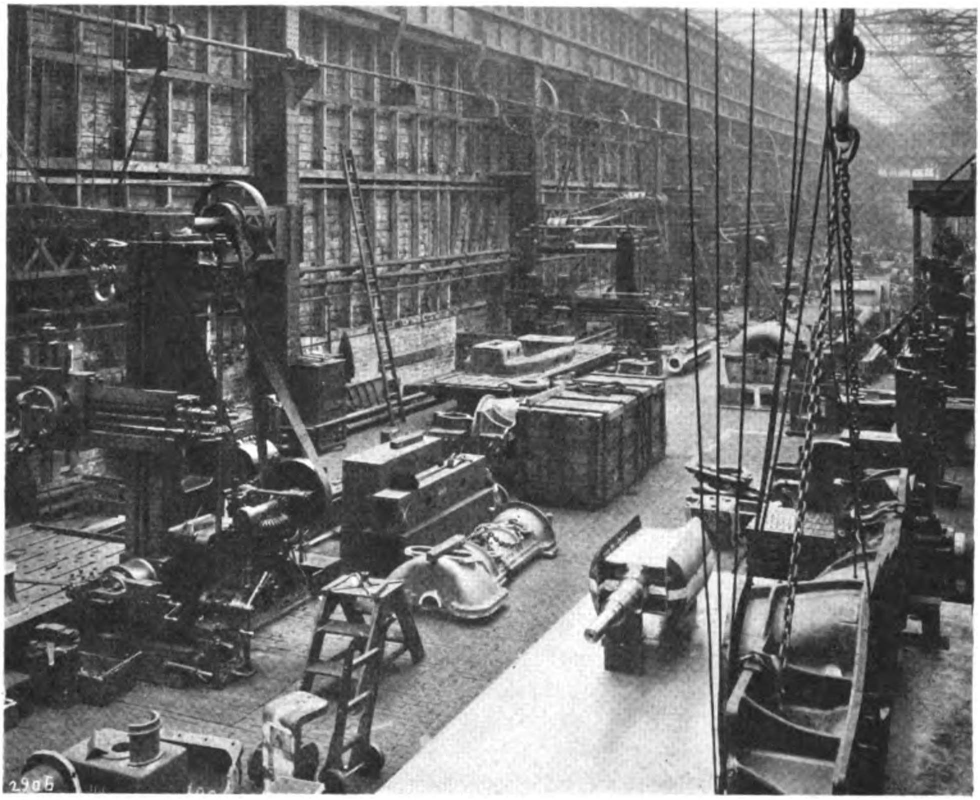


FIG. 4. VIEW OF PRINCIPAL MACHINE BAY.

tioned above is by J. Buckton & Co., of Leeds, and will accommodate work 8ft. 8in. between the standards, and takes a cut 24ft. long. The other planing machine, which stands next to this is by Hulse & Co., of Manchester. It accommodates work 6ft. 6in. wide and has a travel of the table of 22ft. Both these machines are fitted with three tool-holders, which take cuts when the table is travelling in either direction. There is also a large horizontal wall planing machine by Hulse & Co. which is chiefly used for planing bed plate faces, magnet and stator ends, &c. On the opposite side of the same bay is a milling machine of the planer type by Kendall & Gent, of Manchester, which is principally used for milling out claw couplings and similar intricate parts, and is also found very useful for keyseating in large spindles, &c. It will take parts 4ft. square between the standards, and the table has a travel of 8ft. 6in. Close by this machine is a vertical lathe by Richards & Co., of Broadheath, which will take work 6ft. in diameter and has two tool-holders on the cross side.

Turning to the large lathes, the largest of these is a treble geared lathe by W. Muir & Co., of Manchester, having 4ft. centres and a bed 35ft. long and three self-acting slide rests. It is provided with an extensive series of pulleys in order that it can be run over a very wide speed range. Its principal work is turning, grooving, and facing up the parts of large shafts, as well as the tipping of the ends of the blades so as to make them all of the same length radially. To turn off the ends of these blades (projecting as they do from the shaft in some cases over 12in.) requires some very careful work and high speed of running, only the very lightest of cuts being permissible. In certain cases in which the turbine shafts are bladed with steel blades the tips are ground off by means of a high-speed electrically driven emery wheel mounted on the slide rest. There is also a similar lathe standing close by which is generally used for turning very large armature work and cast-steel rotors for revolving field alternators, and for the grooving of large commutators, &c. There is a heavy screw-cutting lathe by Hulse & Co. with 24in. centres and 30ft. bed. Another machine worthy of note is a large turret lathe by Alfred Herbert, of Coventry, which is used for heavy boring work; it has an inclined turret which takes six tools.

Perhaps the most interesting machine tools are two large boring mills, the larger of which is capable of boring turbine cylinders up to 10,000kw. capacity. These mills were specially designed and built for Messrs. Parsons, the larger by Butler & Co., of Halifax, and the smaller by Dickinson & Co., of Keighley. They are both of the horizontal type with traversing bars and heads, and have also rising and falling tables which are fitted with cross-slides to enable the work to be accurately set. Their special work, as before mentioned, is the boring out of the insides of the turbine cylinders. The cutting of the grooves for the reception of the cylinder blades is also done by these machines, a special boring bar and apparatus being used which automatically feeds the grooving tool radially outwards, until sufficient depth of groove has been cut, this being indicated by an automatic gear on the end of the boring bar.

Another machine worth mentioning is a large chuck lathe made by Lang & Co., of Glasgow, which is used exclusively for machining the special discs to be used for building up certain of the turbine shafts, further mention of which will be made later. This lathe is arranged with a special head stock so as to enable a uniform cutting speed to be automatically maintained on any diameter of work. There are numerous other large lathes, shaping machines, milling machines, boring mills, &c., but as these are of the ordinary type they do not require special mention here.

A large marking-off table 24ft. long by 10ft. wide, and constructed in three parts,

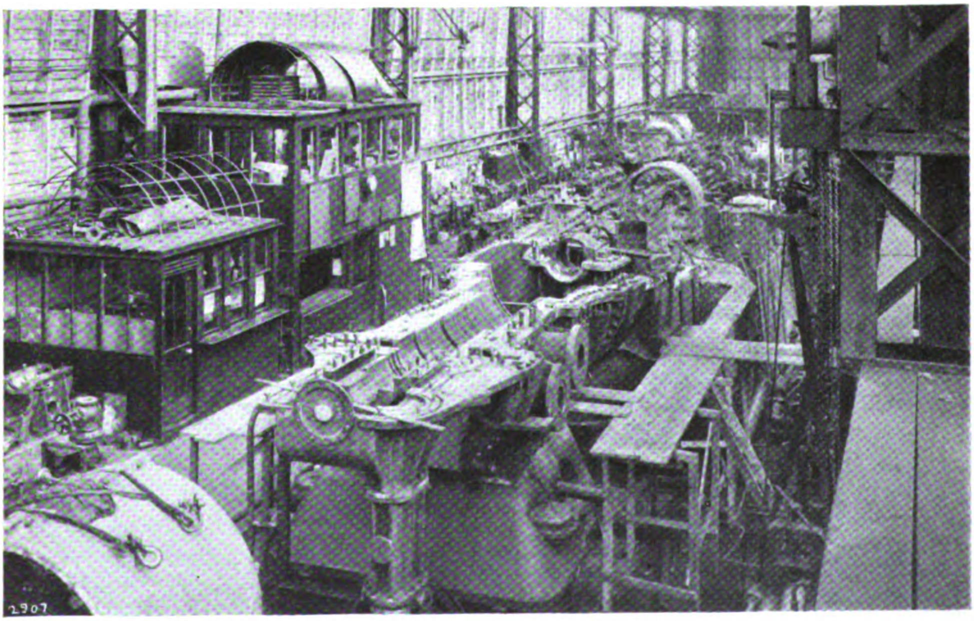


FIG. 5. 5000KW TURBO-ELECTRIC PLANT UNDER ERECTION.

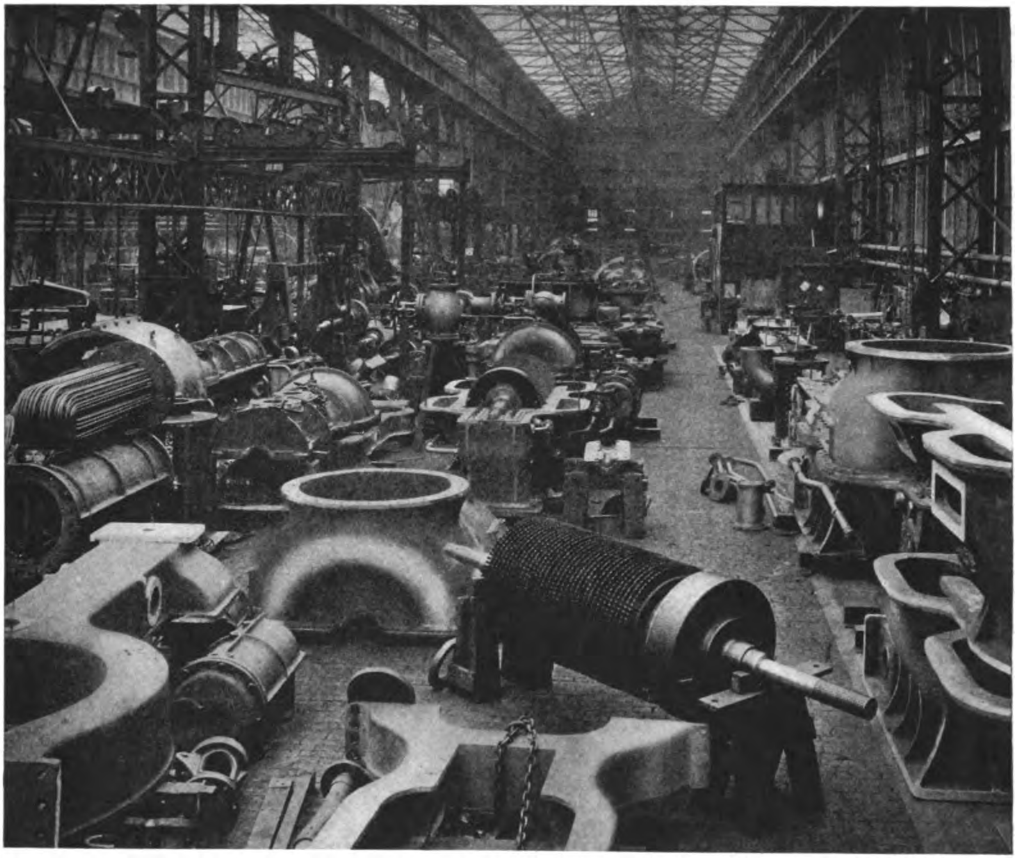


FIG. 6. THE BLOWER ERECTING SHOP.

is also situated in the machine bay. A large power press by Taylor & Challen, of Birmingham, is found extremely useful for making the brass and steel stampings required principally in the construction of dynamos.

Fig. 4 shows a general view of a portion of the machine shop.

At the west end of the shop is situated a large store for the reception of the small standard parts which are made in the various other departments of the works. These parts after having been inspected and tested by the gauging department are all arranged and classified for the various lines of machines for which they are intended. Above this store are arranged the various offices of the Works Managers' Department, from which a clear view of the whole of the operations carried on in the two main bays can be obtained.

A railway siding communicating with both ends of the shop gives every facility for the receiving and rapid despatching of work.

Erecting Shop.

The fitting and erecting bay has every modern convenience for the rapid assembling and erection of the various parts after they leave the machine shop. A compressed-air main runs the whole length of the building and serves the usual type of pneumatic labour-saving tools. Numerous electrically operated portable drilling and milling machines are also seen in operation.

On the occasion of the writer's visit there were altogether about thirty-five plants in course of erection, ranging from 150kw.

to 5000kw. in output, among which may be mentioned two of 5000kw., two of 4000kw., one of 1500kw., one of 1200kw., and seven of 1000kw. There were also eleven plants of the "mixed pressure" type, which type has been developed to utilise the previously wasted energy of exhaust steam available principally in iron-works and colleries.

As the "mixed pressure" turbine forms a new departure in turbine engineering the following description will no doubt be interesting.

The turbine is contained in a single steam cylinder, which is divided into two portions, the smaller end being bladed to efficiently expand steam at boiler pressure down to a pressure slightly below atmosphere, and the larger end to expand the exhaust steam from a pressure slightly below atmosphere down

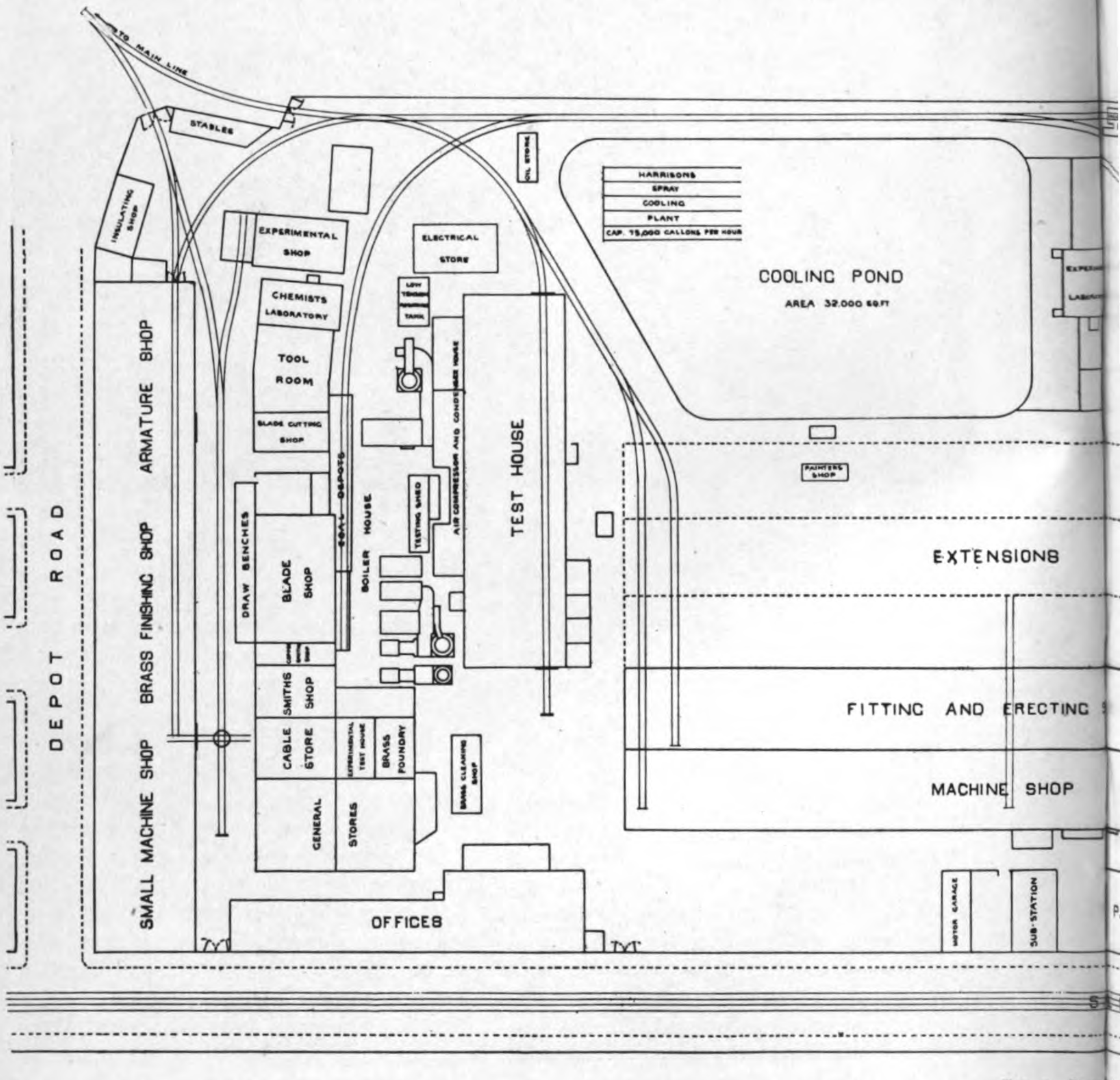
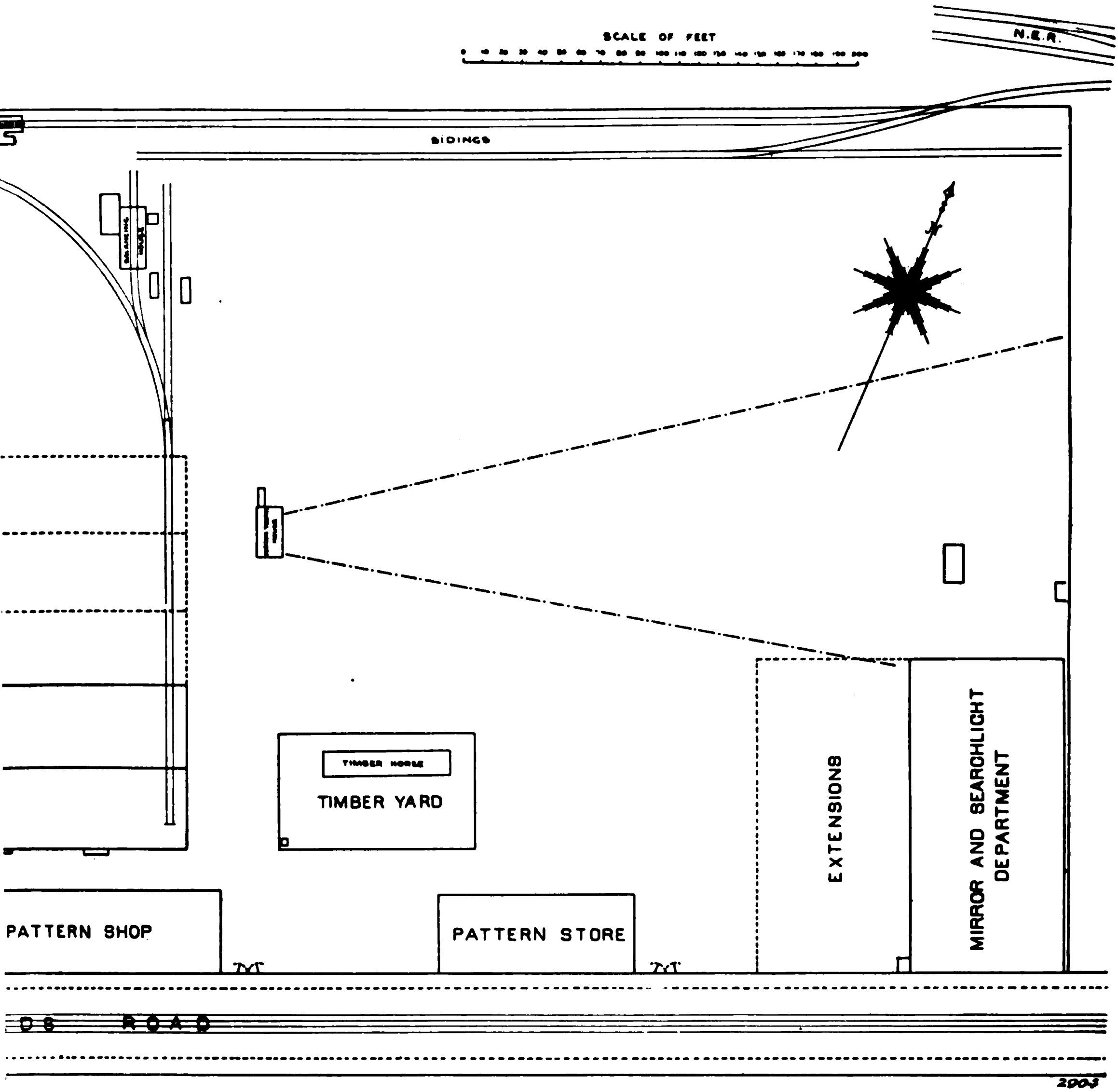


Fig. 7. Plan

to that of the condenser. Separate inlet ports are provided for the admission of high-pressure and exhaust-pressure steam, and each inlet communicates with an independent steam chest containing regulator and runaway valves. The turbine is provided with two centrifugal governors, one of which operates by means of a positive trip gear the two runaway valves; the other, through the medium of two steam relays, operates the regulator valves of the two sources of steam supply. The speed governor is so arranged as to give preference to the utilisation of exhaust steam whenever it is available; but when the load on the generator is greater than can be supplied by the exhaust steam, or when no exhaust steam is available at all, the governor automatically admits the necessary quantity of high-pressure steam to keep the plant in



HEATON WORKS.

operation. The high-pressure portion of the turbine is also provided with a bye-pass valve, which enables the high-pressure steam to be admitted to a lower-pressure stage of the turbine in order that heavy overloads may be dealt with.

This form of turbine combines the advantages of an exhaust steam turbine with those of a high-pressure condensing turbine, and when tested under all conditions has been found to give extremely good results.

Fig. 5 is a view of a 5000kw. machine in course of erection in the fitting shop, while Fig. 6 shows the portion of the shop allocated to the blowing engine department, in which can be seen several large turbo-driven blowing engines of about 1500h.p. each.

An interesting process to be seen here is the building up of those turbine and blowing engine shafts which are required to run at somewhat higher speeds than usual. These spindles consist of a central solid shaft of high-quality spindle steel, on to which are forced, by means of a hydraulic press, a number of steel discs, each carrying as a rule one row of blades. The discs are of low carbon steel possessing an exceedingly high elastic limit. They vary in thickness from 1in. to 3in. and are turned to a special section to enable the stresses due to centrifugal force to be evenly distributed. Each disc before being pressed into position on the shaft is carefully balanced and run up in a testing machine to 50 per cent. above its maximum working speed. The hydraulic press above referred to is by Henry Berry & Co. of Leeds, and is capable of exerting a maximum pressure of 300 tons. It has two rams each 10in. in diameter with a travel of about 12in. The hydraulic pumps are operated from the main countershaft. An ingenious apparatus similar to an ordinary steam engine indicator is attached to the press and records a pressure diagram of every disc as it is pressed into place.

Another interesting operation is the shrinking together of the various parts which go to build up large turbine drums of the standard type. A deep pit is provided for this operation into which the drum portion is lowered endways, and is here heated to a predetermined temperature by means of gas rings. When the right temperatures have been obtained, the various parts are placed accurately in position and the whole allowed to cool. It will be easily understood that the parts which are put together by the above methods are machined with extreme accuracy.

The blading department, in which the finished blades are assembled and secured into their respective spindles and cylinders is situated at one end of the erecting shop. At this point, perhaps, it would be interesting to describe the various methods adopted for securing the blades, in all of which the full strength of the blade is maintained unimpaired right into the root fixings. The majority of readers are no doubt aware that this question has lately been the subject of much controversy, and it may be interesting to note that Messrs. Parsons have standardised three distinct methods of fixing, each of which has its own special features. Firstly, we may take the most generally adopted system, namely that in which the blades and caulking pieces or "sections," as they are called, are fitted separately and individually into their grooves. In this method a complete groove is filled up with blades and sections, and the latter then firmly caulked by hand with specially-shaped caulking tools. The ends of the blades which fit between the sections are serrated, as also are the sides of the grooves, thus ensuring the utmost security against their coming loose; indeed, they are so firmly fixed that it is impossible to pull them out by mechanical means, the blade itself invariably breaking first.

The principal feature of the second method is that the sections, instead of being separate individual pieces, are made out of a long, continuous root strip somewhat resembling a comb, with teeth curved in such a manner that they suit the shapes and angles of the blades. After the blades are fixed into this strip it is bent to the radius of the spindle or cylinder, and caulked home in a similar manner to that described above.

In the third method blades and sections are used as in the method first described, the difference being that the roots of the blades and the sections themselves are pierced with a small hole and alternately threaded on to a wire and driven up tight in a former, curved to the right radius for the part of the cylinder or spindle into which they have to fit. These segments are afterwards caulked up tight in the turbine grooves in the usual manner.

In all cases the blades are "laced," that is, the tips are provided with notches into which a strip of brass wire is inserted and brazed. The tips of all blades are thinned away to a fine edge so as to entirely do away with the risk of any damage being done should the blades by accident come in contact with the walls of the cylinder or spindle.

Test House.

We will now turn our attention to the testing department, where every plant manufactured is subjected to thorough tests as nearly as possible in accordance with the conditions under which it is intended to work. To enable this to be done there is a large boiler plant, condensing plant, cooling pond, and water resistance tanks, the latter for producing the artificial load necessary in testing the electrical generators. These appliances are extremely interesting, and it is proposed to describe each separately.

The test house itself is a large brick building, 200ft. long by 50ft. wide, and 38ft. from floor to eaves. There are two electric travelling cranes, one by Joseph Adamson & Co. and the other by Spencer Bros., each running the full length of the building, and capable of raising a maximum load of 20 tons. They are each controlled from a cage attached to the crane. The floor is of solid concrete slightly sloped to a gully at one side in order to dispose of the water that may be discharged from plants. As will be seen from some of the photographs, the steam pipe range is provided with innumerable branches and valves so that plants can

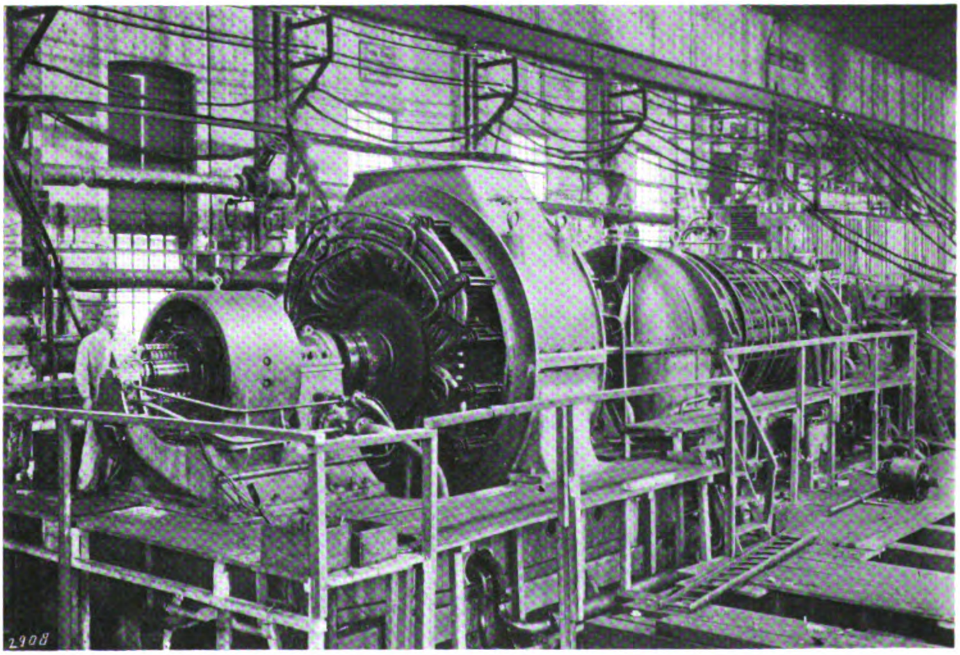


FIG. 8. 5000KW TURBO-ALTERNATOR UNDER TEST.

be practically connected up to any part of it. On the floor level, immediately under the steam range, and running the whole length of the building, is the exhaust steam main, which is 3ft. in diameter. It also has branches at intervals of every few feet for connecting to machines. The exhaust main leads to two large surface condensing plants, which will be described later. Fig. 8 shows a 5000kw. machine running on load in the test house.

In one corner of the test house are three turbo-generators, two of 150kw. and one of 200kw. capacity. These plants were originally used for supplying both electric power and lighting throughout the works, but as the demand gradually outgrew their capacity, it was decided to take all the current from the Newcastle-upon-Tyne Electric Supply Company, Ltd. As the system of supply in the works had been for only 110 volts continuous current, the Supply Company found it necessary to put down a special sub-station inside the works yard for converting their high-tension 6000-volt three-phase alternating current supply to 110 volts continuous current. This was deemed necessary as the Supply Company's continuous current system is for 480 volts, and converting from the high-tension mains was the easiest solution for such a low-pressure supply. Under this arrangement the above turbo-generators are now only used in cases of emergency or when a heavy overload occurs.

Boilers.

The boiler plant is of a very representative type, and comprises the following:—

2 marine boilers each capable of steaming 5000lb. per hour at 150lb.
1 Lancashire boiler capable of steaming 6000lb. per hour at 170lb.
1 Babcock & Wilcox boiler capable of steaming 10,000lb. per hour at 350lb.
1 Stirling boiler capable of steaming 15,000lb. per hour at 350lb.
1 Woodeson boiler (by Clarke, Chapman, & Co.) capable of steaming 15,000lb. per hour at 350lb.

All the boilers are hand fired except the Woodeson, which has an electrically driven chain grate stoker with hand-fed hoppers.

There are three chimneys, one built of brick and two of steel, the former being 80ft. high and 6ft. in diameter, and the two latter each 80ft. high and 8ft. in diameter. The two steel chimneys are fitted with the Sturtevant system of induced draught, the fans, 9ft. diameter, being steam engine driven. These chimneys and the end of the boiler house can be seen in Fig. 9. A separately fired Babcock & Wilcox superheater can supply superheated steam when required at the rate of about 22,000lb. per hour at 100deg. Fahr superheat. It will be seen from the above that about 56,000lb. of steam per hour can be raised for testing purposes, which is sufficient to run on full load a machine of about 3750kw. capacity, a testing service which very few, if any, other engineering firms can accomplish.

Condensing Plant.

The plant used for condensing the exhaust steam from the turbines on test consists of two complete units of the surface type, having a combined cooling surface of 4500 square feet. The circulating pumps are of the centrifugal type, and the air pumps of the Parsons' patent vertical single-acting compound type. In one case they are operated electrically, while in the other case a steam engine is used. It is hardly necessary to say that both condensers are fitted with the Parsons' patent vacuum augmentor, which ingenious apparatus enables a vacuum of within half an inch of the barometer to be easily maintained. A vacuum of this high order may be new to some readers, so, perhaps, a brief description of the vacuum augmentor will be of interest.

The augmentor itself consists of a small nozzle discharging high-pressure steam into a contracted pipe connecting the main condenser to the air pumps. The steam, issuing at a high velocity from the nozzle, carries along with it by its ejector action the non-condensable air and vapour (residue of the condensed steam) from the main condenser and delivers it through a small auxiliary condenser to the air pumps. The condensed steam leaves the main condenser by a separate pipe, which is water sealed and flows by gravity directly to the air pump. Fig. 10 shows the diagrammatic arrangement of the vacuum augmentor coupled to a surface condenser. It will be seen that the augmentor is simplicity itself, having absolutely no moving parts. Its assistance in increasing the vacuum ordinarily obtainable is so valuable that in many cases of turbines of the high-pressure condensing type it enables the steam consumption to be reduced by as much as 10 per cent., and considerably more when the turbines are of the exhaust steam type.

The air pump delivery from each condensing set is arranged to discharge into two large calibrated measuring tanks. By this means the steam consumption of the various turbines under test can be measured with extreme accuracy. The water, after passing through the tanks, runs by gravity to the hot-well. It is an interesting fact that, owing to the clean nature of the exhaust steam from turbines, the hot-well water is used in the chemical and experimental laboratories as distilled water.

Testing of Generators.

With regard to the manner in which the machines are tested, the usual procedure after the erection of the plant is for the turbine spindle to be run up to its maximum speed—that is, 20 per cent. above normal—in order to test the mechanical strength and also to ensure the perfect balance of the parts. The dynamo rotor is then coupled up, and is similarly tested. This having been completed, the open circuit curves of the dynamo are taken, and the machine is afterwards put on full load. A full load test is then carried out, which includes taking the temperature readings

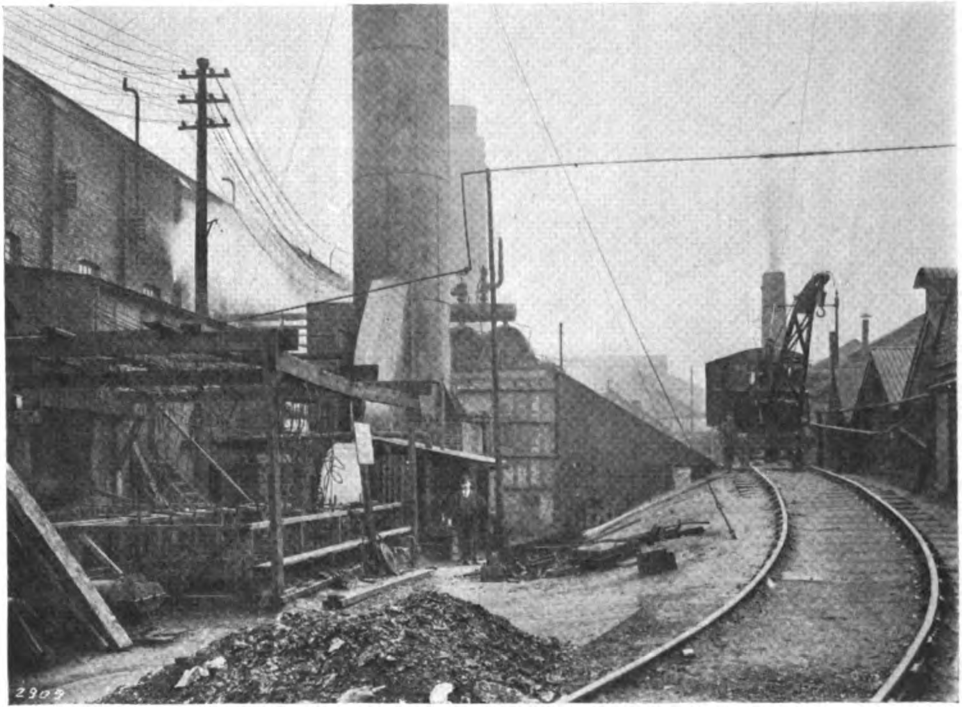


FIG. 9. BOILER PLANT. LOAD TANK FOR TEST PURPOSES IN FOREGROUND.

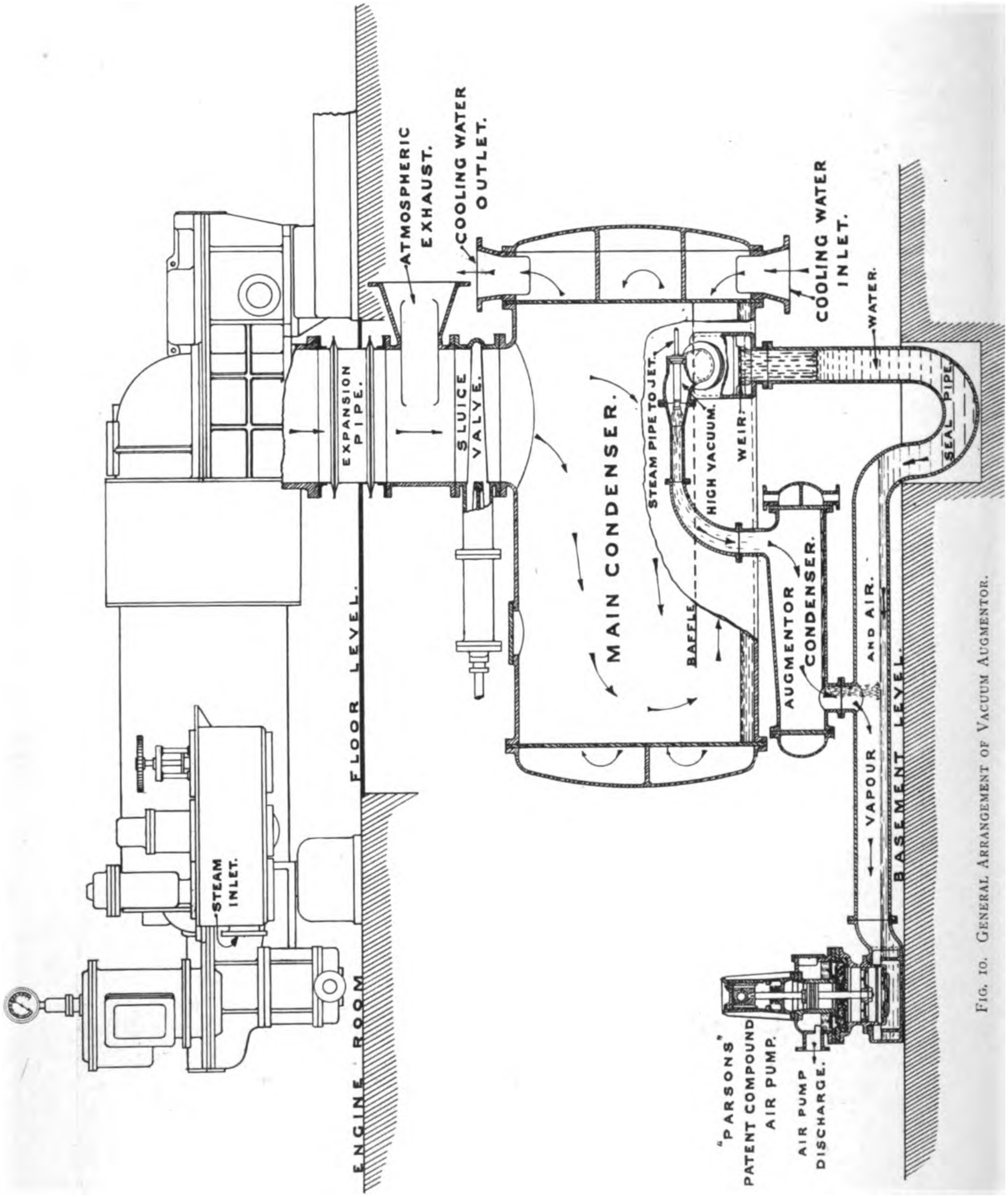


Fig. 10. General Arrangement of Vacuum Augmentor.

of the dynamo and the steam consumption of the turbine. The turbine during this trial is also subjected to a maximum temperature test—that is, the cylinder is heated to a temperature considerably higher than the actual working temperature.

This full load run completed, the overload capacities of the plant are tested up to the specification, and both the governing and voltage regulation are also recorded. In the case of alternators it is of course necessary to test them thoroughly with the same power factor as that of the system on which they are intended to run. To enable this to be done choking coils are inserted in the circuits, and by regulating the number of turns of cable in the coils any desired power factor can be obtained. After these trials have been completed the whole plant is opened up for inspection, and, if found satisfactory, it is then ready for the official trial.

In the above tests the output of the plant is measured by either a Kelvin balance or a Kelvin astatic wattmeter, which instruments are calibrated and kept in order by the makers, who make frequent inspections of the same. These balances, &c., enable plant up to 12,000 volts pressure or 4000 amp. output to be thoroughly tested. The artificial load necessary in testing a generator is obtained by means of iron plates or wires submerged in water. Two arrangements are provided, one suitable for low-voltage machines and the other for high-tension work. The former consists of a concrete tank into which the above-mentioned plates are suspended. A constant supply of water flows through, the level of which can be varied in order to adjust the load on the machine. This tank can be seen in Fig. 9. For high-tension work a similar contrivance is used, but for the sake of safety it is placed in the centre of the cooling pond.

This reference to the testing of plant would be incomplete without mention of the "Oscillograph," a complete installation of which instrument is in constant use. It is of the Duddell type, made by the Cambridge Scientific Instrument Company, Ltd. By the use of this apparatus photographs of the voltage and current curves of the machines are taken under all conditions, and by a study of the results obtained important modifications of design can be carried out. Interesting investigations on the behaviour of continuous current plant are also made. In addition to the ordinary dry-plate camera attached to the instrument, the apparatus also includes a cinematograph camera. By the use of this, very important and interesting results are obtained, such as the effect of switching on and off of feeders on load, &c.

In certain cases the contract may be of such a nature that the turbine has to be tested with its own condensing plant. This was the case, for instance, of a large 3000h.p. turbo-blowing engine recently built for the Hanyang Iron and Steel Company, of China. Fig. 11 shows this engine as erected in the test house. The condensing plant was arranged on the floor, over which the turbine and blower were erected on a steel girder framework. The complete installation was thus run for several days under absolutely working conditions.

Cooling Pond.

The cooling pond, the position of which can be seen on referring to the plan of the works shown in Fig. 7, and a photograph of which is shown in Fig. 12, has a cooling surface of 32,000 square feet and a capacity of 700,000 gallons. Over a portion of this pond is erected a spray cooling installation by Messrs. Harrison & Gjers, of Middlesbrough. The installation was designed to cool 75,000 gallons of water an hour from 85deg. to 75deg. Fahr., but in practice is found to give much superior results. This type of cooler was adopted as it was the only one on the market which would work with a head on the nozzles of only 5ft., for by working with this low head it was not necessary to instal extra pumping plant. It has the further advantage of being the cheapest and at the same time the most

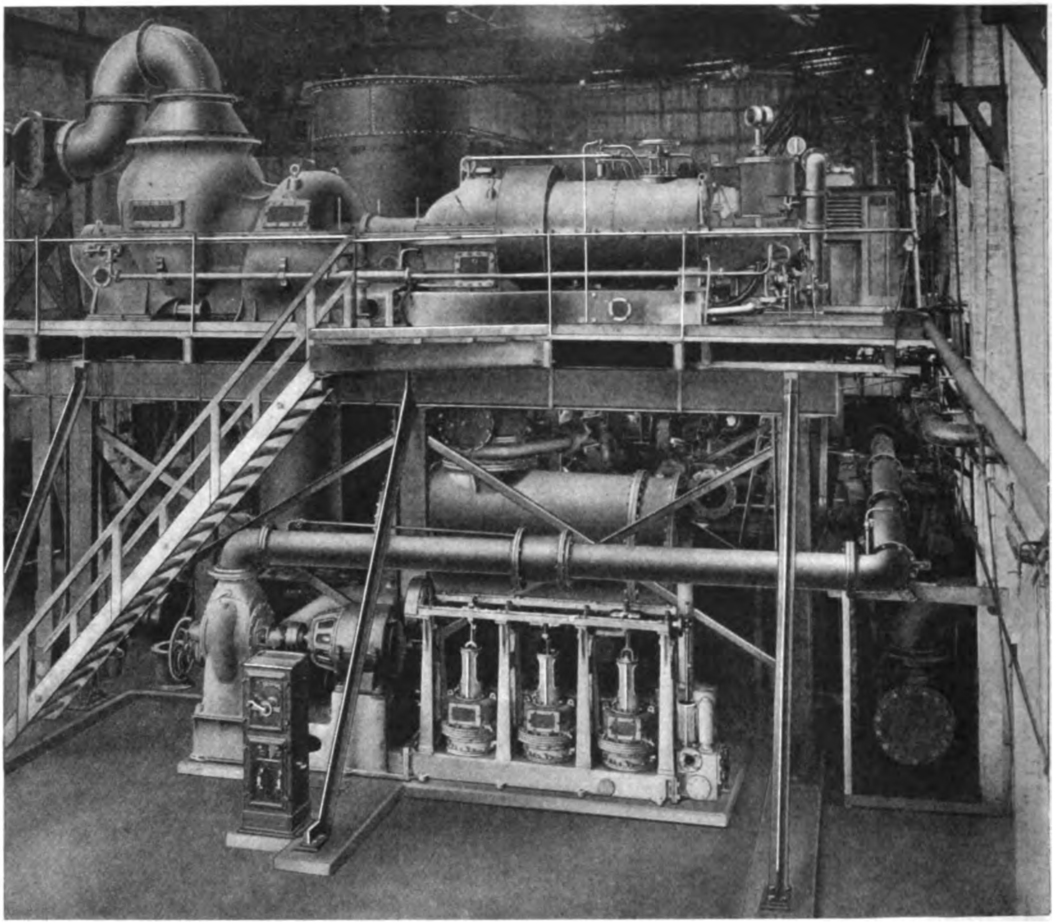


FIG. 11. TURBO-BLOWER BUILT FOR THE HANYANG IRON AND STEEL COMPANY, CHINA.

durable cooling apparatus obtainable, and the jets do not easily get out of order.

Blade Shop.

There has recently been inaugurated at Heaton Works a department for the manufacture of the special material used for the making of the turbine blades, the process of the fixing of which has been described previously. Great care is taken in every process to ensure the blades being of uniformly high quality, and everything is subjected to the most rigorous inspection.

The blading material, or "strip" as it is termed, leaves this shop in lengths of 10ft. or 12ft., and is transported to the blade-cutting department, in which are a number of automatic machines, many of which are worked by compressed air, for cutting the strip into various lengths, and also for serrating, grooving, and tipping the material to make the finished blade. It will be readily understood that the various forms and sections now used have been the outcome of many years of careful experiment, and it is by no means exaggeration to say that hundreds of different forms have been tried until the present high state of standardisation has been arrived at.

From the above it must not be assumed that experimenting in this direction has ceased, as new samples are constantly being made for trial purposes. It need hardly be mentioned that in order to obtain the most satisfactory results it is necessary that the blades should be most carefully made to gauge sizes, and to ensure accuracy in this direction an elaborate set of gauges is used, through which the material is tried before being sent to the cutting shop.

Tool Room.

The tool room is also of modern organisation. The shop itself is fitted out with every modern convenience for the accurate manufacture of gauges, jigs, and small tools. There is a gas-fired furnace used for the hardening of small milling cutters, worm-wheel hobbs, and similar appliances.

Electrical Shop.

The electrical shop contains plant and apparatus of the most up-to-date description. All the machine work is done in the same lathes as the turbine work, and the parts are then sent to the electrical shop for assembly. Every separate part of the revolving portions is carefully balanced independently of the remainder, so that when the armature or rotor is finished, in many cases the smallest possible amount of balancing is necessary, and often the revolving parts are run right up to full speed without requiring any additional balancing.

The shop is equipped with a complete plant for punching laminated discs for both continuous current and alternating current machinery. The plates are all papered on one side in a special machine, and every plate is carefully scrubbed to remove the rags caused by punching and shearing. The shop is also equipped with two vertical and three horizontal winding machines; the latter are principally used for forming the compensating windings which are fitted to all the firm's continuous current plants. These compensating windings are a special feature of the continuous current generating sets, and have now been in use for some six years. By means of this winding it is possible to secure exceptionally good commutation without any need for shifting the brushes, and loads can be carried for short periods up to 50 per cent. above the normal rating of

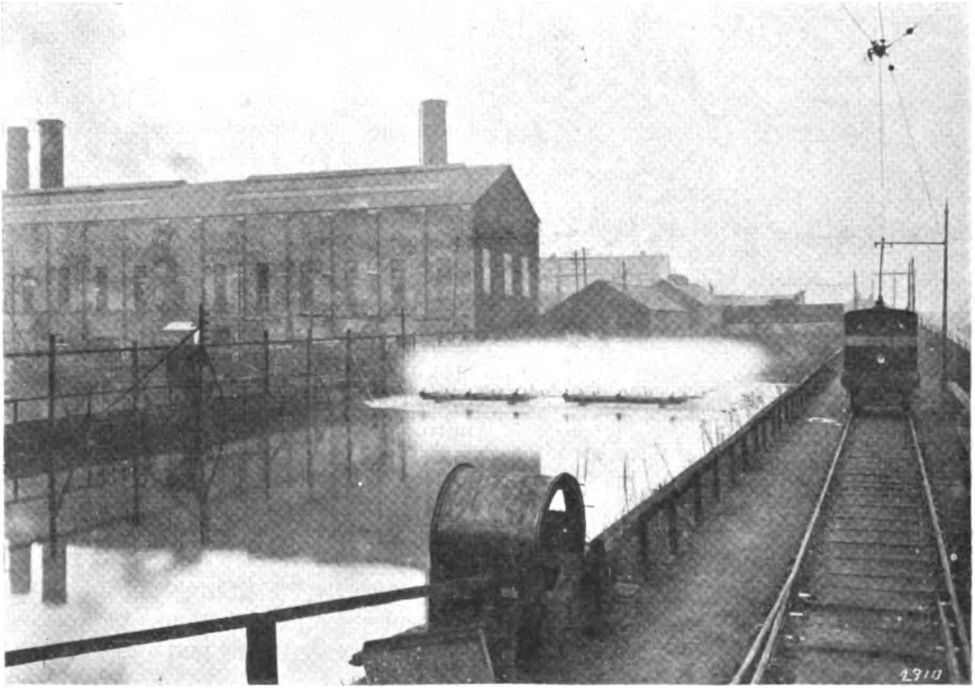


FIG. 12. GENERAL VIEW OF COOLING POND.

the dynamo. A special feature of this winding is that the brushes do not need extremely accurate setting on the commutator, since they can be rocked backwards and forwards a considerable distance without causing sparking.

Another piece of apparatus which may be seen in the electrical shop, and which has aroused considerable interest recently, is the arrangement of leakage paths and coils, by means of which the alternators are compounded for constant voltage at all loads. This arrangement is fitted to the exciter and consists of a magnetic leakage path bridging the exciter poles and carrying a winding through which the main current from the alternator passes. The effect of this is to cause an increase in the exciter voltage when the load comes on to the alternator, thus compensating for the armature reaction and giving a constant voltage at the terminals. The apparatus can also be adjusted to give a rise in voltage with increase of load in exactly the same way as is common practice on continuous current plants working on heavy power loads.

A separate building is provided for preparing the insulation and impregnating coils and taping, and a large heater stands outside the armature shop which will accommodate the stators of the largest revolving field alternators. In the test house will be found two smaller vacuum heaters, in which smaller parts can be rapidly dried.

Balancing House.

This shop is constructed entirely of ferro-concrete and is equipped with special plant and gear to enable any sized turbine shaft or armature to be run up to its maximum speed and balanced. The part to be balanced is placed in two adjustable bearings of rather novel construction, which are lubricated with oil under pressure. A suitable sized pulley is fixed to the shaft, and it is rotated by belt from a 100h.p. motor running at any speed between 500r.p.m. and 800r.p.m.

There is, of course, a great difference in the amount of balancing which is required to be done, some shafts running right up to top speed without any adjustment, whilst others require small weights or balancing pieces before they are finally passed as being satisfactory.

Mirror Department.

The mirror department consists of five buildings of corrugated iron, each 76ft. by 30ft., provided with weaving-shed roofs, giving an exceedingly good north light. In these buildings the well-known Parsons searchlight reflectors are manufactured. This manufacture was started about twenty-one years ago for the purpose of providing searchlight reflectors for use on the Suez Canal, and these first ones were made with one axis a parabola, and the other a hyperbola, so as to give a flat beam. Afterwards parabola mirrors for ordinary searchlights were manufactured, and gradually the greater part of the supply to the British Government passed into the hands of Messrs. Parsons, the Mangin and the Schuckert mirrors, which were made on the Continent, being displaced. The standard mirrors used are 36in. and 24in. diameter, but the whole place has been laid out so that reflectors of 6ft. can be manufactured, and some of 5ft. 2in. have actually been already supplied to the British Government. A speciality is the parabola ellipse mirror, of which large numbers have been manufactured, and in which the beam from the mirror is concentrated on a narrow slit and then diverges out beyond; thus the projector can be placed behind a narrow loophole, which only offers a small target for shot, and yet the whole of the light illuminates objects beyond. Besides supplying to the British Government, large numbers of mirrors have also been supplied to foreign Governments and private firms.

Nearly all the various shops are interconnected by railways, which are electrified by the overhead trolley system. An electric locomotive by the Brush Company is used for haulage purposes, and an electric travelling jib crane for lifting purposes.

W. G. TURNER.

A SERIES OF COMPARISONS BETWEEN ELECTRICITY AND GAS.

I.—For Lighting Service.

(Continued.)

THE higher the c.p. required the more apparent does the superiority of electricity become. Following are a few notes on high c.p. sources of illumination, then a table (Table II.) of running costs is compiled, just as was Table I. in last month's article, and conclusions are drawn from the data so obtained.

High C.P. Sources.

The general advantages of electricity over gas in this application are the same as detailed in the earlier part of this article, but the far greater degree to which economy is now effected by electricity is obvious from the subjoined estimates.

As a general point of significance in this connection it may be noted that public houses—notoriously, and perhaps unfortunately, the best illuminated class of buildings—almost invariably employ flame arcs.

The objection urged against the early flame arcs—the frequent retrimming necessary—has now been entirely removed. In some cases the difficulty is overcome by the use of magazine carbon holders, but a more satisfactory and economical method (the waste in carbon stumps being less) is to employ very long carbons. With "downward feed" as now universally adopted, the length of carbon is no disadvantage.

Like all electrically operated apparatus, arc lamps are capable of central control without the expense of clockwork, by-passes, &c., which have recently been introduced into street gas-lamp working. (To the writer's certain knowledge it is no uncommon thing for several gas lamps in one street to burn all day and become extinguished, by the officious clockwork switch, just as dusk falls!)

In the case of arc lamps there can be no question as to their robustness and suitability for rough usage, but the gas mantle has a very curtailed life when exposed to the weather in streets, railway yards, &c. The life of 200 hours assumed for these mantles is an extremely liberal estimate for such services.

Arc lamps can be easily and safely lowered to the ground for trimming and cleaning, but such a convenience is impossible with gas lamps. Largely owing to this possibility arcs can be hung on much higher standards than gas lamps and a much more even and pleasing distribution of light is so obtained. (It is a well-known axiom in illuminating engineering that as little *direct* light as possible should enter the eye from the illuminating source.)

The excellent fog-penetrating powers of flame arcs (particularly the "Excello" type) is no mean advantage in such cities as London, Glasgow, &c. The rich colour of the "flame" arc and the excellent general illumination obtained, without the projection of sharp shadows and consequent eye fatigue, besides loss of value of the light, have made its advance extraordinarily rapid.

Some of the special uses of arc lamps to which gas is quite inapplicable may be mentioned, viz. :—

1. Projectors and searchlights, particularly of the naval and military types.
2. Copying and portraiture where an especially uniform illumination is

required by light of high actinic value. (Such light—blue—may be obtained from an arc by running it at a high voltage, say 160 volts, though for the three-colour process 80 volts is sufficient.

High c.p. gas sources depend essentially for their efficiency either (1) on the enriching of the coal gas used, or (2) on the use of some "patent" gas, or (3) on the use of "high-pressure" gas. The use of specially treated (chemically) or manufactured gas is at once severely handicapped by the standing, running and maintenance charges of the special plant required. Even with such auxiliary plant the efficiencies obtained (rarely over 50c.p. per c.ft. per hour) are not nearly so high as is later shown to be necessary if gas is to compete successfully with flame arcs.

The use of "high-pressure" gas is open to precisely the same objections. Special mains are also required. The leakage from an ordinary gas system (pressure = about 1in. to 2in. of water) has been recorded at 5 per cent. of the total consumption. It is not pleasant, therefore, to contemplate the precautions necessary to avoid disastrous leakages from a system in which, in some instances, the pressure rises to 54in. of water (above atmospheric pressure).

The life of mantles on high-pressure systems is much curtailed: apart from mechanical injury the optical efficiency very rapidly falls.

The Keith gas system, with its auxiliary plant, is only equal to a flame arc using energy at 1½d. per B.O.T. unit, even assuming the maker's figures for the gas-light (2230 candles for 1d. per hour). As this figure assumes constant mantle c.p., and a life far in excess of that actually obtainable, the comparison is not nearly so favourable to the gas system (apart from the capital and upkeep charges of the auxiliaries of the latter).

"Self-intensifying" mantles depending practically on chimney draught have the disadvantages of rapid clogging of burners with dust, reduced mantle life, and increased blackening of surrounding ceilings, &c.

Relative Running Costs of High C.P. Units: -

The cost of installation of gas and electric sources of high c.p. have been already dealt with, hence the costs reckoned in Table II. are, on the one hand, cost of current + carbon consumption, and, on the other, cost of gas + mantle renewals.

The various conditions of comparison are as below. The lower rates now assumed per B.O.T. unit are perfectly justifiable, practically every supply company offering energy at charges not in excess of 2½d. per unit to consumers such as would use arc lamps (shops, theatres, &c.). In many cases the rate is already reduced to 1½d. per unit, and in quite a number of supply areas power consumers are allowed current for lighting, at power rates up to 10 per cent. of their maximum power demand.

Data relating to miniature arcs are not given. Few illuminating engineers recommend their use, the ordinary incandescent-filament lamp being available up to several hundred c.p., beyond which limit the full-size arc lamp is applicable. Even the miniature arcs, however, compare favourably with gas, and their actual cost per 1000c.p.-hours can be evaluated precisely as indicated in the table.

Conditions of Comparison:—

Gas at 2s. 9d. per 1000c.ft.

Electricity at 2½d., 1½d., and ¾d. per B.T.U. in turn.

Gas-mantles — life 200 hours, 1000c.p. mantles, cost of replacement 1s. 3d. per breakage. Efficiency, 20c.p. per cubic foot and 30c.p. per cubic foot in turn (the lower efficiency is the more nearly correct as a mean). The carbon consumptions assumed for the various arc lamps are obtained from much practical experience, and the efficiencies are the mean results of authoritative tests.

Taking the flame arc as the most efficient electrical illuminant, the efficiency of gas

TABLE II.—CONDITIONS OF COMPARISON AS ABOVE.

Source.	Hours per Trim.	Life Hours.	Mean Hemi-spherical C.P.	Efficiency.	B.O.T. Units (or cubic feet) per 1000 hours.	Cost* Carbons (or Mantles) per 1000 hours.	Cost of Current (or Gas) per 1000 hours.			Total Cost per 1000 hours.			Total Cost per 1000 C.P. hours.		
							B.T.U. at 2½d.	B.T.U. at 1½d.	B.T.U. at ¾d.	B.T.U. at 2½d.	B.T.U. at 1½d.	B.T.U. at ¾d.	B.T.U. at 2½d.	B.T.U. at 1½d.	B.T.U. at ¾d.
D.C. Open Arc	17	—	1000	0.52 watt c.p.	520	225	1300d.	780d.	390d.	1525d.	1005d.	615d.	1.525d.	1.005d.	0.615d.
,, Enclosed Arc	150 to 250	—	700	1.2	840	75	2100	1260	630	2175	1335	705	3.11	1.91	1.01
A.C. Open Arc †	15	—	900	0.6	540	250	1350	810	405	1600	1060	655	1.77	1.18	0.73
D.C. Flame Arc ..	17½	—	3400‡	0.26	884	275	2210	1326	663	2485	1601	938	0.729	0.47	0.275
A.C. Flame Arc ..	17	—	3000	0.30	900	275	2250	1350	675	2525	1625	950	0.842	0.542	0.317
Welsbach High-Pressure Gas	—	200	1000§	20c.p./c.ft. 30c.p./c.ft.	50,000c.ft. 33,300c.ft.	75d. 75d.‖	— —	1650 1100	— —	— —	1725 1175	— —	— —	1.725 1.175	— —

* These carbon costs are the mean results of much actual working experience.

† The economy in labour resulting from enclosure is similar to that in the D.C. case, and hence need not be tabulated here.

‡ The 4500 m.h.c.p. unit is still more efficient, but for uniformity 10amp. arcs have been adhered to as far as possible in this article.

§ This c.p. is probably more nearly the *maximum* c.p. of the mantle than the m.h.c.p. (The *maximum* c.p. of the flame arcs varies from 5000 to 7000c.p. in most cases.)

‖ This item would be higher in this case, since to even approximately retain the higher efficiency much more frequent mantle renewals would be essential. The c.p. of a mantle falls by as much as 50 per cent. after a few hours' burning at most. (The c.p. of an arc is constant always.)

mantles to equal this arc, with gas at 2s. 9d. per 1000c.ft. and mantle life = 200 hours, would have to be as follows:—

Electricity per B.T.U. ..	2.5d.	1.5d.	0.75d.
Total cost per 1600c.p.-hours	729d.	470d.	275d.
Mantle renewals	75*	75	75
Total gas cost	654	395	200
Cubic feet per hour	19.80	11.95	6.06
Requisite c.p. per c.ft. per hr.	50.5	84.0	165.0

* With the h.p. gas necessary for this efficiency the mantle renewals would be heavier.

In connection with these results two points may be noted:—(1) An efficiency of even 50c.p. per cubic foot per hour is only obtainable, with gas, by the use of special auxiliary apparatus largely detracting from the economy otherwise obtained. This efficiency then only lasts during a few hours of the mantle's life. The efficiencies 84c.p. and 165c.p. per cubic foot are impossible. (2) As already mentioned, the greater proportion of the arcs in use are supplied at from 1½d. to 2d. per unit, while the rate is as low as ¾d. in quite a number of instances.

From Table II. it is clear that the economy in carbon and labour costs of the enclosed arc is dearly bought, since the efficiency is halved (chiefly owing to absorption by the two enclosing globes). In special positions, however, where long burning hours are required, its use is advisable.

The numerous obvious deductions from Table II. need not be pointed out at length. The general conclusion is that electric arcs are more than twice as efficient as incandescent gas, with electricity at 2½d. per B.T.U. With lower rates the economy is proportionately increased.

As proving that the figures of Table II. are not biased, but rather insufficiently favourable to the electric arcs, may be quoted the appended results given by an author at the Institution of Electrical Engineers as *actual working costs, excluding carbons.* (The latter charge varies with the type of carbon burnt: this is a matter for individual choice, though, for high efficiency, the carbons recommended by the makers should be employed. The carbon charges in Table II. are based on the assumption that the correct carbons are burnt.)

Type of Lamp.	Watts.	Cost per 1000 c.p.-hours (m.sph. c.p.).
Oriflamme	350	0.40d.
Weinert	350	0.55d.
Excello	470	0.57d.
Santoni	420	0.70d.
Carbone	1000	1.00d.
Open Arc	500	1.50d.
Enclosed Arc	500	2.00d.
Enclosed Midget Arc ..	250	3.00d.

In concluding this section one more actual example of the economy of flame arcs may be cited :—

In the street lighting of the city of Melbourne, a certain gas company first installed 34 lamps having an aggregate c.p. of 8500c.p., which was later extended to 42 lamps, totalling 12,400c.p.

The lamps installed were—

7 Lucas lamps, each 1000c.p. = 7000c.p.
2 ,, ,, ,, 400 ,, = 800 ,,
13 ,, ,, ,, 200 ,, = 2600 ,,
20 ,, ,, ,, 100 ,, = 2000 ,,
42 lamps ... ... Totalling 12,400 ,,

The cost of operation of these lamps over a period of 5 years (running nightly from sunset to 12 midnight = 2186 hours per year) averaged £291 per year.

This corresponds to 2.59d. per 1000c.p.-hours, a figure which shows that the estimate of 1.725d. per 1000c.p.-hours is certainly not exaggerated (for gas and mantles alone in Table II.). *Flame arcs being installed and the yearly cost being the same, the light obtained was more than three times as great,* the units being :—

15 arcs of 3000c.p. each = 45,000
or 22 ,, 2000 ,, = 44,000

(the municipality being allowed the choice between these two sets of lamps).

Convenience and Risks.

The most elementary and perhaps the most appealing convenience of electricity to the domestic user is the ease with which the light is switched on. No matches and fumbling in the dark are required.

Recently an approximation to this convenience has been made in gas lighting by the use of the ordinary "bye-pass," familiar to everyone by reason of its pleasant habit of becoming extinguished by draughts and remaining so till the accident becomes pungently evident. These bye-passes may be pneumatically operated by an imitation electric switch. The valve is worked, just as the old pneumatic bells were operated, by pressing a "button" on to a flexible ball connected to the bye-pass valve through lead piping. Anyone who ever used pneumatic bells will appreciate the possibilities of failures so introduced. However, the pneumatic pushes are a convenience, though to state that they are more convenient than the electric switch is obviously absurd.

A remarkable statement made in the catalogue of a firm of gas manufacturers whom one would have thought rather better informed, is that these pneumatic pushes "can be operated from the door, but *without batteries, coils, or any of the drawbacks incidental to electricity.*"

The writer has yet to discover the tumbler switch needing "batteries and coils" for its operation: the closing of such a switch should be quite spectacular in its effects!

Passing on to the other points of comparison—gas companies admit that water meters are liable to freeze, so becoming inoperative and cutting off the supply, while dry meters are inaccurate in their registration. Such defects are apparent in no electric meters: the latter can readily be calibrated when in position and thereafter vary very little in their accuracy.

Incandescent burners require continual cleaning, especially at the gauze distributors in the base of the burner. This is more particularly so in the high-pressure gas systems, and is very troublesome in works where the atmosphere is always laden with dust particles.

The "rise-and-fall" chandeliers and pendants, now so commonly used in living rooms, are far safer when electricity is used than when gas is employed. In the latter case the renewal of the water seal is a continual source of trouble. The water therein smells very fœtid, and should the seal become low and the fitting then be lowered, there is grave risk of instantaneous explosion.

When electric light first came into general use insurance companies regarded it as a source of added fire risk, and accordingly increased the premiums in cases where it was employed. "Fused electric cable" was for a long while, and even now is occasionally, the favourite way of accounting for fires whose origin was quite inexplicable. In most cases there were not the slightest grounds for the imputations laid on the electrical installation. Fortunately, companies now recognise that electricity is certainly no more dangerous than gas; the higher premium has been abolished in every case, and in some cases gas is penalised instead. Undoubtedly the fire risk with gas is far more serious than with electric supply.

The risk from electric shock is absolutely nominal. The writer has never met with a case in which shocks could be obtained off the system at all, and cannot remember a case in which a shock, from the normal house voltage, has proved fatal. Certainly the toll is many times less than that claimed by gas explosions.

Table "standard" lights are becoming very popular now, and the immense superiority of electricity in this application is at once obvious. Gas mantles are entirely unsuited to the continual lifting to which these lamps are subject, and, moreover, the excessive heat emitted from an incandescent gas mantle makes it very unsuitable for use on a small table standard and makes such decorative shades as are possible with electric light quite impossible.

Lighting schemes can be arranged in any desired manner with electric light, but with gas there are always the risks inseparable from naked flames and intense heat. If an electric lamp be broken the incandescent filament is at once "burnt out" and extinguished; if a gas globe be broken the fire risk becomes infinitely greater. With gas mantles there is always the danger of their fracture, and subsequent falling against the globe, cracking the latter and firing the shade (which in decorative work is usually very inflammable in nature). Artistic illumination, so largely practised in modern interiors, can be executed with electric light in a manner unapproachable with gas.

When using electric glow lamps, shades of any artistic design, or of any shape required for efficient illumination in the desired manner, can be fitted without the least risk of damage to the shade by heat. For this reason reflectors are very much more varied and efficient in design for electric than for gas lighting.

The possibility of using filaments and globes of any desired shape exposes another use of electric light of even more special nature, viz., the illumination of operating tables, of billiard tables, &c., where, by using frosted tubular lights, a remarkably even illumination can be obtained with none of the disadvantages of gas.

The persistence with which gas designers imitate electric light accessories seems to indicate a slight acknowledgment, on their part, of the superiority of electricity in this respect. Many lamps which the public take for electric arcs are really high-pressure gas mantles enclosed in globes designed to imitate those of electric arcs. The mistake does not always produce an impression which one would wish to be associated with electric arc lighting.

Health.

This is a most important phase of the comparison and one which is too frequently left entirely out of consideration by the consumer. The products of the combustion of 1 c.ft. of coal gas supplied in London and passed by the Metropolitan Board of Gas referees include:—1oz. water and 0.57c.ft. carbon dioxide (CO_2), besides which $1\frac{1}{3}$ grammes of sulphur dioxide (the oxide of sulphuric acid) are liberated per 100c.ft. of gas burnt. The carbon dioxide in normal air is 0.03 per cent., while 0.08 per cent. is unpleasant and even unhealthy (this corresponding to the condition of the air in a theatre at the end of a play). Hence the danger of the CO_2 evolved by gas consumption can be realised.

To keep the atmosphere of a gas-lit room reasonably pure not less than 60c.ft. of air should be supplied per burner (20c.p.) per hour. With the advent of incandescent gas lighting the quality of gas has been allowed to decrease. Thus within the last twenty years the c.p. per cubic foot has fallen from more than 20 to about 17c.p. per cubic foot per hour. This is chiefly due to the admission of poisonous impurities, chiefly sulphur compounds, hence the injurious products of combustion are rapidly becoming even more dangerous than above (the above results being based on an analysis taken before the recent relaxations were allowed).

Within the last few years, since the abolition of the restrictions on sulphur contents of coal gas, the amount of sulphur per 100c.ft. has risen from 15grs. to nearly 90grs. in many cases. The resulting effect on health is obvious.

An interesting figure, given in a certain gas company's annual report, and it is by no means exceptional, is that *the gas unaccounted for, after leaving the works = more than* 5 *per cent.* of the total, *i.e.*, of the millions of cubic feet of gas yearly generated in towns 5 per cent. leaks out into the open, and into houses, unburnt—not a particularly wholesome state of affairs as regards public health. To say that this deficit is accounted for by errors in meter readings is hardly plausible, for not only are meters usually too high in their records, but also the deficit has been *consistently* about 5 per cent. for the past twenty years, a state of things which no company would allow to exist by reason of faulty meters alone.

The deleterious effect of electric glow lamps on health is, of course, absolutely nil, there being no combustion of material. In the case of arc lamps the rooms illuminated are always of such size as to make the effect of any fumes very slight. Flame arcs admittedly do produce a fume of irritating nature, but these lamps are inherently most needed out of doors on account of their immense c.p. (5000 mean hemispherical c.p. is a common size of lamp). In cases where they are used indoors several simple and effective ventilating services have been brought out to remove all fumes.

The ordinary arc, burning unimpregnated carbons, evolves a purely nominal amount of CO_2 as its sole product of combustion, This amount is *very* small, its effect on the composition of the air in the room being quite incapable of detection. In enclosed arcs, owing to the exclusion of air and consequent diminution of combustion, the CO_2 produced is still less, and amounts to only a few cubic inches per striking of the arc, for once the globe is filled with CO_2 further combustion is practically nil till the arc has been extinguished and the globe refilled with air by diffusion of the CO_2, a very slow operation, and one which normally only occurs once a day.

No one can possibly urge with the least degree of conviction that gas is at all comparable with electricity from the health standpoint.

Indirect Costs.

There are many indirect charges affecting the comparison between electricity and gas, and on examining these one by one it will be found that they *all* contribute to the greater gross economy of electricity, so that ultimately the superiority of electricity, for domestic as well as for high c.p. use, becomes incontrovertible. The advantage is not very decisive, for low c.p. units, when current and lamp renewal charges alone are considered, but on the basis of *total cost* electricity is far the cheaper.

It is to be remembered that in a few

years, with the B.T.U. at 1d., the economy of electrical energy will be indisputable *at every point*, not merely as a whole, as is the case in some of the instances here cited.

The average consumer, asked as to the chief indirect economy of electricity, would undoubtedly reply, "The less cost of re-decorating ceilings, &c." This economy is so great and so obvious that little need be said regarding it. This point will not appeal much to the wealthy, who are continually having their rooms re-decorated; but the main class concerned in the consumption of electrical energy and in the possibilities of economy by its use is the "middle" class, whose struggles to "make both ends meet" are proverbial, and to whom the extension of the period during which a ceiling or wall remains presentable from one year to three or more is a very important economy.

There can be no doubt that the life of clothing, furniture, carpets, &c., is correspondingly prolonged by the absence of fumes where electric light is employed. This point is important when comparing electricity with gas for heating services. The deleterious effects of fumes from gas fires on delicate materials in the drawing-room, as well as on the more robust upholstery of the dwelling-room, is established as a point in favour of electric radiators.

It has been shown under the health section that the economy resulting from improved hygienic conditions is not so fanciful as gas engineers would have us believe.

The net economies that can be effected by using electricity for other purposes than lighting—in fact, by organising a complete domestic electrical scheme—is a subject which the author hopes to deal with in a further series of articles.

In some towns where special rates are charged for very special conditions of supply, such as the limited hours maximum demand system, &c., a special fee of 5s. per year (never more) is charged for making the measurements necessary for the calculation of the reduced charges. The payment of such a fee is at once recouped by the greatly decreased gross bill.

In this article the object has been to bring together data regarding a number of uses of electricity and gas. The comparison has been made as fair as possible and results of actual experience have been utilised rather than the imaginary claims of makers. With regard to the cost figures given, these are believed to be accurate to date. It is extremely difficult to obtain definite nett quotations from firms, but the estimates given are based on replies sent by large makers on special request: hence if either party—gas or electrical engineers—feels aggrieved, it has only its manufacturing representatives to thank.

The general conclusion to be drawn from the above data and investigations is that electricity is far superior to gas in all lighting applications provided that the high-pressure mantles, which alone have revived the cause of gas illumination, are compared with the latest metallic-filament lamps or flame arcs according to the c.p. of the units compared.

THE ELECTRIC DRIVING OF PRINTING PRESSES.

THERE can only be one answer to the question—How is it that electric driving in printing works has made such rapid strides of recent years? And that is because it pays.

In no instance are the all-round benefits to be derived from electric driving so evident as in printing works. The particular advantages attending the use of electric motors for the driving of printing presses are as follows: Increase in output; superior quality of the work turned out; economy effected in power by having each press individually driven; cleanliness.

The chief difficulty experienced with older methods of drive was to obtain the necessary variation of speed according to the work on hand, and when once the speed had been attained to keep it uniform and free from any sudden alteration such as tends to take place when a second machine driven off the same countershaft started from rest. Any sudden variation in speed is almost sure to cause the print to be out of register and slurring to take place. The speed range required on a press may be anything from 5 up to 200 revolutions of the cylinder per minute. This applies more especially to rotary presses, and it will be seen that to get this with coned pulleys or any

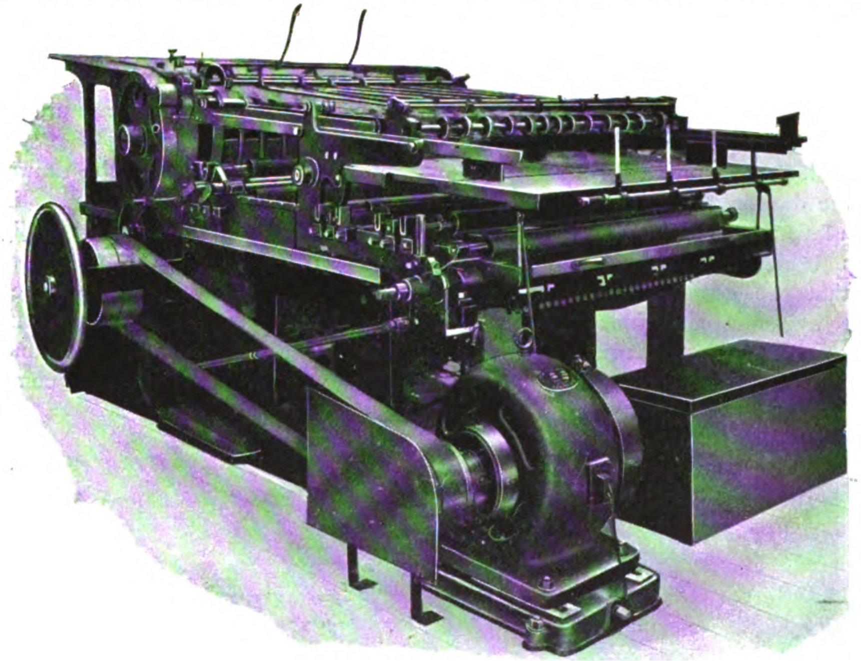


FIG. 1. FURNIVAL TWO-REVOLUTION PRESS ELECTRICALLY-DRIVEN FROM A MOTOR BY MEANS OF A BELT RUNNING ON THE FAST AND LOOSE PULLEYS OF THE MACHINE.

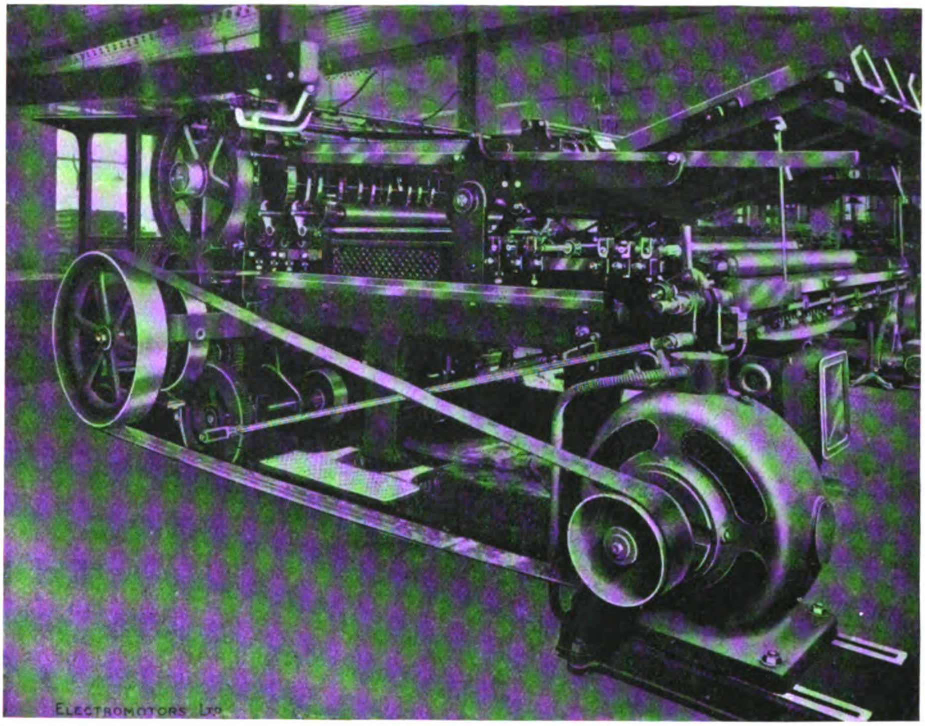


FIG. 2. LETTERPRESS MACHINE DRIVEN BY BELT, USING FAST PULLEY ONLY. THE MACHINE IN THIS ARRANGEMENT IS STARTED AND STOPPED BY THE ELECTRIC SWITCH.

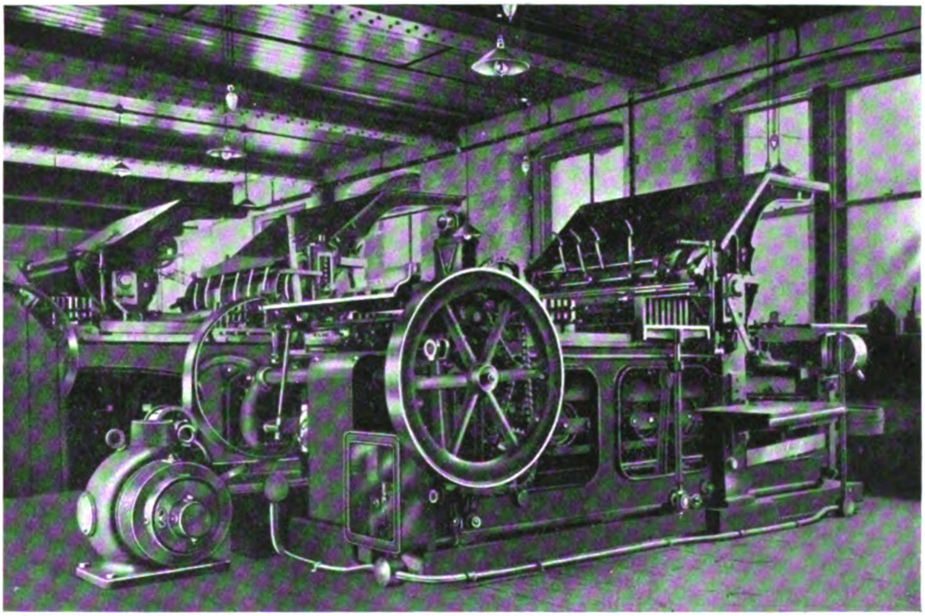


FIG. 3. LITHO PRESS DRIVEN BY MEANS OF A SHORT FLEXIBLE BELT AND JOCKEY PULLEY. THE POSITION OF THE JOCKEY PULLEY IS ADJUSTABLE, AND IS KEPT AGAINST THE BELT BY SPRING TENSION.

mere mechanical device is practically impossible.

It has become almost universal practice to install a separate motor to each press, although the total b.h.p. so installed is higher than if the presses were grouped together and driven by one motor through countershafting. The latter method is only to be recommended in the case of a set of machines all of which would be required at one time. However, this is very seldom the case with printing presses, as it more frequently happens that some are making ready whilst others are running, not to mention continual stoppages for supplies of fresh paper, slight alterations to formes, &c. Besides, however careful the supervision may be it is frequently necessary to run one press alone on a rush job; it is at such times that 50 per cent. of the power given out by the motor is wasted in driving a long line of shafting and belting.

For these reasons, amongst others, it is now the usual practice to fit each press with its own motor, which may be either shunt or compound wound, as large starting torque and a wide range of speeds is essential.

It will therefore be seen that the main cause of the success of the electric drive is its adaptability as regards speed requirements. This is chiefly governed by the electric motor-controlling gear, which will be considered later. The mechanical methods of transmitting the power from the motor shaft to the press may be either by belt, chain, or spur gear.

Driving by Belt.

The belt drive is the most commonly used of the three methods, especially in small plants where prime costs have necessarily to be kept low. In these cases it is usual to fix fast and loose pulleys on the presses, so that the "inching," *i.e.*, the small movements

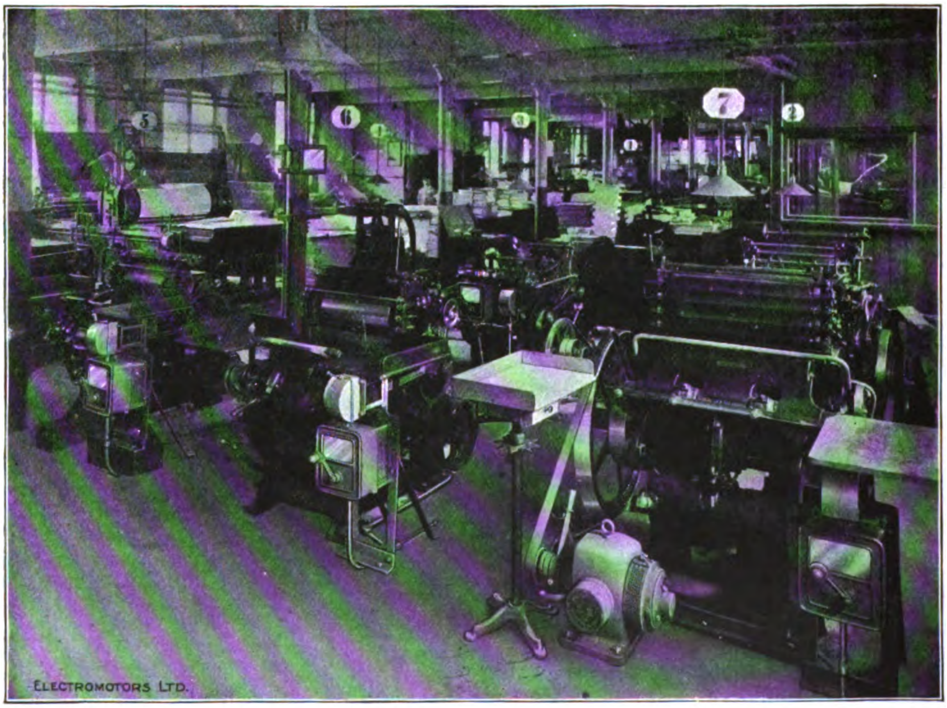


FIG. 4. GROUP OF PLATENS DRIVEN BY MOTOR WITH ADJUSTABLE JOCKEY PULLEYS. D.P. SWITCHES AND REGULATORS ARE ALSO SHOWN UNDER THE TABLES.

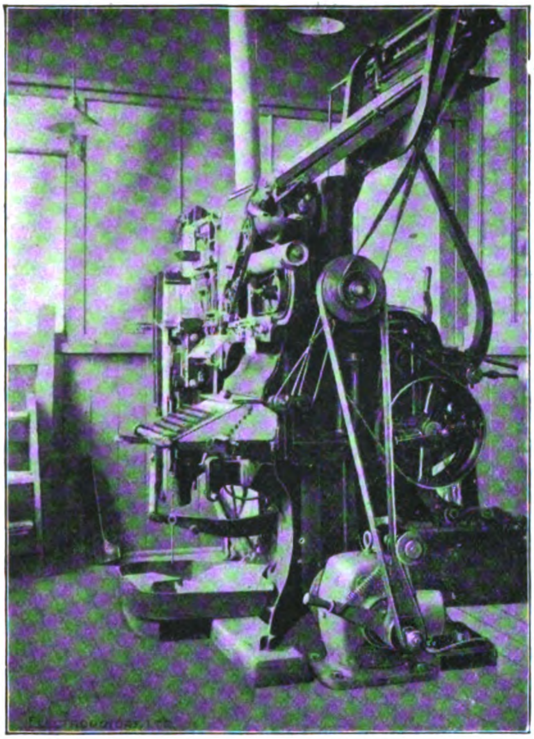


Fig. 5. Linotype Machine driven by Electric Motor fitted with Jockey Pulley.

required of the press bed in dressing the form or cylinder, is done by means of a mechanical striker, the motor having been started up in the usual way to drive the loose pulley on the press or a line of shafting (Fig. 1). This arrangement has the advantage that the wear and tear on the controlling apparatus is a minimum, but on the other hand power is being continually frittered away in running the motor when it is not actually required for power. With a separate motor for each press the alternative plan of belt drive is to do away with the loose pulley and drive direct on to the fast pulley (Fig. 2). This of course means that the motor will have to be started and stopped every time it is required to move the machine, with the consequent wear and tear of controlling apparatus.

The usual position for the motor is under the feedboard, when possible, as in this position it is well out of the way and gives a good length of belt, which is more satisfactory than a short drive. However, in some cases exceedingly short drives are unavoidable. This is often the case with linotype machines. It is then common practice to fit a jockey pulley to give the belt more contact surface on the driving pulley and so avoid slip. The examples shown in Figs. 3, 4, and 5 are by Electromotors, Ltd., and illustrate typical short belt drives. It will be seen that the tension on the belt is controlled by an adjustable spring. Needless to say, where this type of jockey pulley is employed, the belt must be very pliable and lap-jointed, or preferably an endless belt fitted. These latter, by the way, are to be highly recommended for electrical driving, especially for

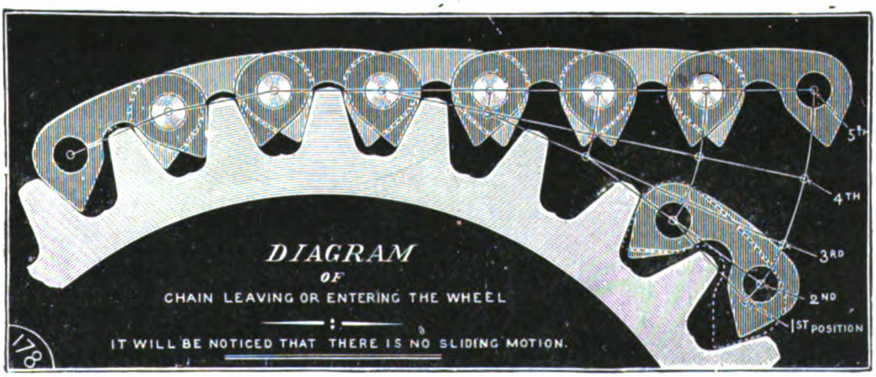


DIAGRAM
OF
CHAIN LEAVING OR ENTERING THE WHEEL
IT WILL BE NOTICED THAT THERE IS NO SLIDING MOTION.
5th
4TH
3RD
2ND
1ST POSITION
178

Fig. 6. The Renold's Chain Driving Gear.

high-speed motors having small pulleys, as when butt-ended joints are used much needless jarring, which causes vibration of the brushes, with consequent pitting of commutator, takes place when the belt joint passes over the pulley.

Chain Drive.

This form of drive gives a more even turning movement than toothed gearing, in that it is not absolutely rigid; it is also particularly useful when the shafts are too far apart to be reached readily by spur wheels. To be efficient much depends on the correct meshing of the chain and sprocket; the correct distribution of the load over the number of teeth; also the links entering and leaving the wheel teeth without sliding action. The illustration (Fig. 6) shows a form of chain manufactured by Messrs. Hans Renold & Co. The speed of chain gear should not be above 1250ft. per minute unless special precautions are taken to see that the lubrication of the links is sufficient. Occasionally it will be found that jockey pulleys are advisable; in such cases they should be made of hard wood or fibre and applied to the back of the chain. If made of metal they tend to deform and burr the links and so cause the chain to run stiffly.

It will be found that the chain drive is very frequently used in printing works, especially with heavy flat bed presses such as the Percelers.

Chains can be run fairly slack, so that the power which is used to obtain the necessary tension on the belt to prevent slipping on the pulley is saved, besides which the wear on the bearings is considerably lessened. The only objection which is raised against chain drive is that the element of safety obtained by the slip on the pulley in the belt drive, should the load be excessive, is non-existent. This need not be so, for a safety device can be introduced into the chain by making either one or more of the bolts in the chain of softer metal than the others, so that they will shear with sudden excessive overloads. In the case of electric drive additional safety is secured by the fuse, which is of such capacity that it blows on excessive loads.

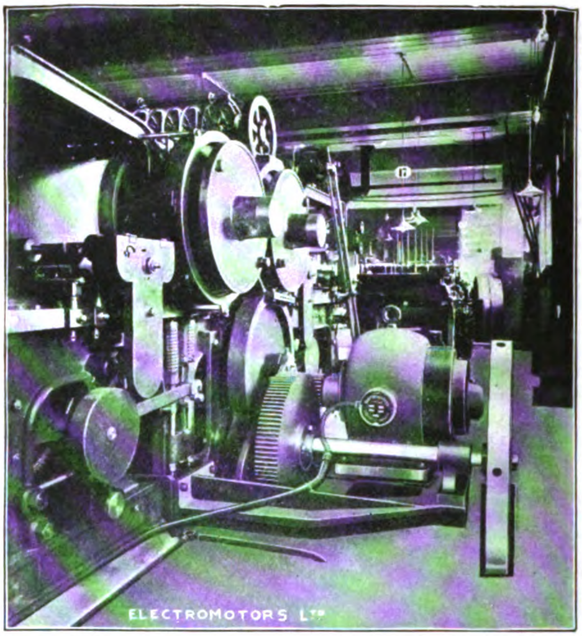


FIG. 7. PERFECTING MACHINE DRIVEN THROUGH GEARING (GEAR CASE REMOVED).

Gear Wheel Driving.

This is the form of drive most frequently employed for large rotary printing presses, in cases when the distance between shafts is small (see Figs. 7, 8, and 9). When rawhide pinions are used the noise is considerably reduced and smooth running obtained. In the motor direct-driven press great care must be exercised to get the teeth properly in mesh or trouble will be experienced by jarring of the teeth being transmitted to the press.

Having thus briefly considered the various methods employed for transmitting the power from the motor to the press, a few of the best-known methods of electric control, with special reference to their application to newspaper presses, will now be considered.

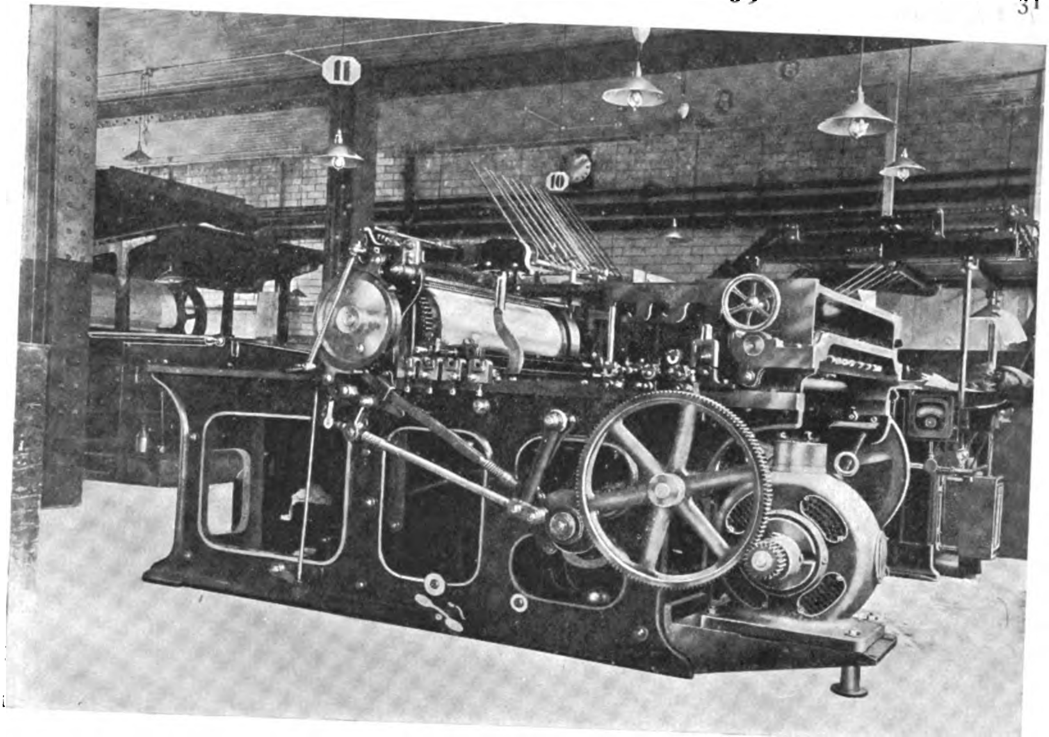


Fig. 8. Double-demy Dawson driven through gearing by Motor on special Bracket.

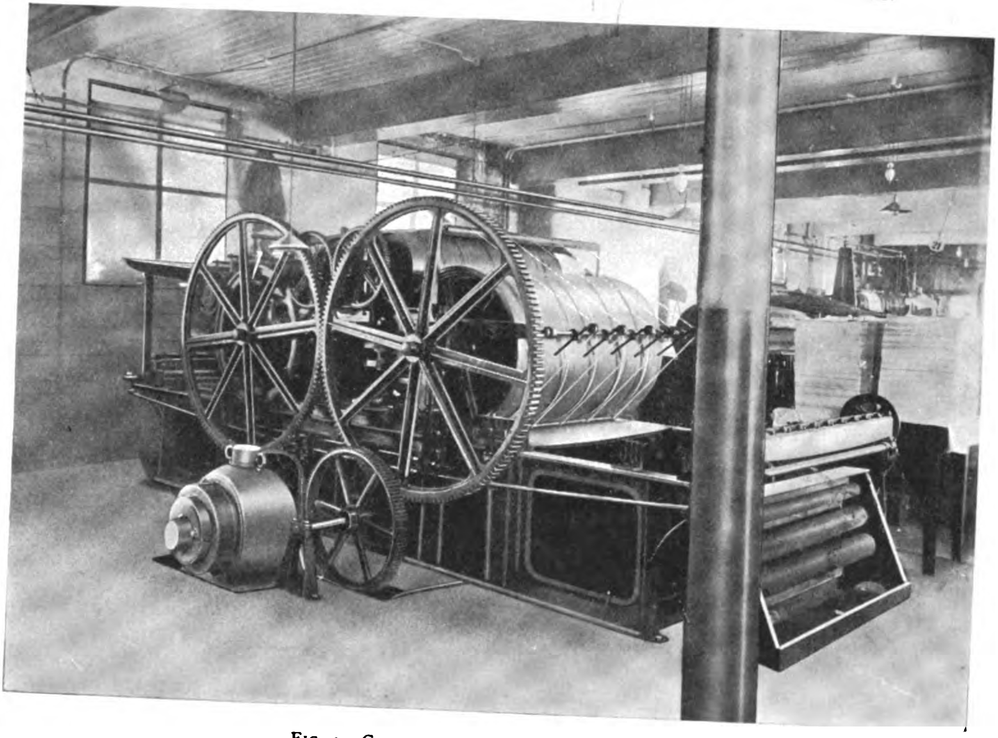


Fig. 9. Gear-driven Quad-demy Perfector.

The Electric Control.

For flat-bed presses, such as quad-crown and quad-demy perfecters and Bremners, it is common practice to control the motors merely by the ordinary no-volt and overload release open-type regulator, fitted with a powerful magnetic blow-out to overcome the sparking caused by the frequent starting and stopping of the press whilst inching. This can only be recommended in cases where the initial cost of installation must be kept as low as possible. As a general rule, it will be found to be far more efficient to install solenoid starters working in conjunction with armature and field regulating resistances to obtain the necessary variation of speed (see Fig. 10). The extra initial cost of these automatic switches should be amply repaid by the advantage gained of being able to control the press from various positions by means of push buttons in the solenoid circuits; the diminution of controller repair should also be taken into consideration. The auxiliary resistances are frequently enclosed in a cast-iron box, which is locked so that the running speed cannot be increased or reduced unless by special sanction of the overseer, who holds the key, thus avoiding any job being spoilt by being rushed through at an excessive speed, or on the other hand unnecessarily prolonged.

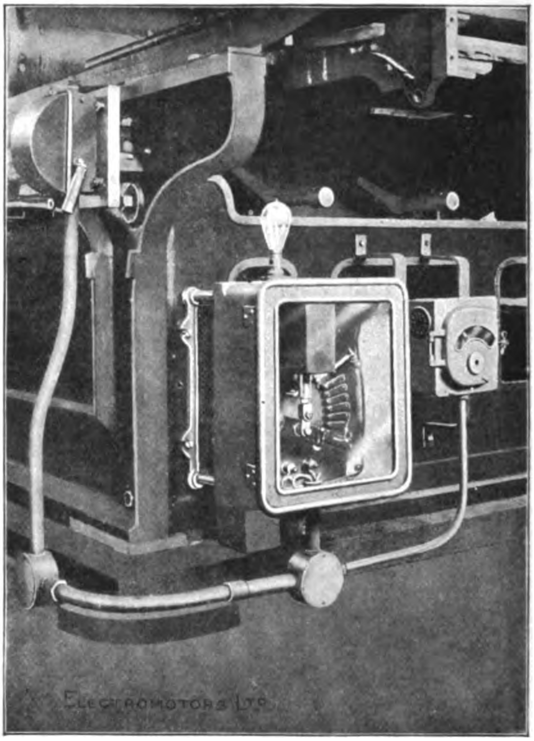


FIG. 10. AUTOMATIC SOLENOID STARTER WITH D.P. SWITCH AND FIELD REGULATOR.

Power Subdistribution Board.

Fig. 11 is an illustration of a type of sub-distribution fuseboard, together with a universal ammeter. The connections are such that, on inserting the plug shown below the instrument in the correct hole, the ammeter is placed in parallel with the fuse on one side of the circuit. On withdrawing this particular fuse it is possible to note the amperage taken by the press under test. The arrangement is now much used, and is far preferable to fitting an ammeter on every press, which is not only expensive to instal, but adds to the parts of the electric system likely to get out of order &c. In the case of large rotary presses it is advisable to have ammeters on every press, as by so doing a hot bearing or other trouble can be detected before serious trouble arises.

Turning now to the control of rotary newspaper presses, it is at once noticed that these entail much closer consideration, as the power of the motors is greater and much economy can be effected by employing a system of control in which the electrical losses are reduced to a minimum.

In order to start a rotary press from rest it frequently occurs that the torque required will be as much as three times the normal; the large torque is of course only momentary, for as soon as the press is got into motion the torque becomes normal. The problem then is to impart a dead slow movement to the press, which can be gradually increased to full speed without any sudden increments in speed, which would tend to break the paper web or strip the gear wheels on the

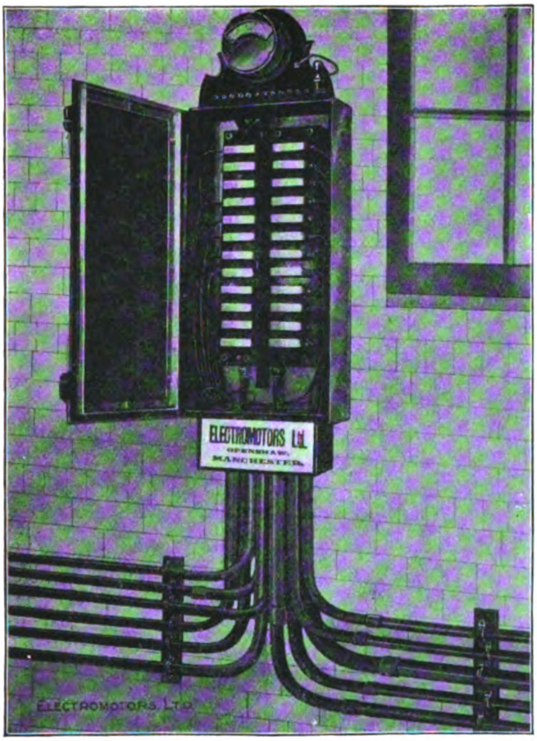


FIG. 11. POWER SUBDISTRIBUTION FUSEBOARD AND AMMETER.

press. Not only is it essential that the increase in speed should be gradual, but the electrical efficiency of running the press at any speed—from inching, which may be about $\frac{1}{30}$th of the maximum speed, to maximum—must be very high, otherwise the loss entailed by running at low speed for bad paper or other reasons may be prohibitive. Amongst the most successful electric control systems at present in use are to be mentioned the Holmes-Clatworthy, Witton-James, Kohler, and the Igranic.

The Holmes-Clatworthy Set.

The general arrangement of this set is well shown in Fig. 12. It comprises a main motor direct geared to the press shaft. On the same bedplate with this motor is mounted a small auxiliary motor connected to the main motor and shaft through worm gearing and an automatic, solenoid operated, jaw clutch. The small motor is used to provide the power for all slow movements of the press, for "plating" and "leading in"; and this auxiliary motor is usually a series-wound machine of about one-tenth the power of the main motor, which is shunt wound. The controller shaft is commonly operated by hand, but in some of the larger sets hand power is replaced by a small push-button circuit

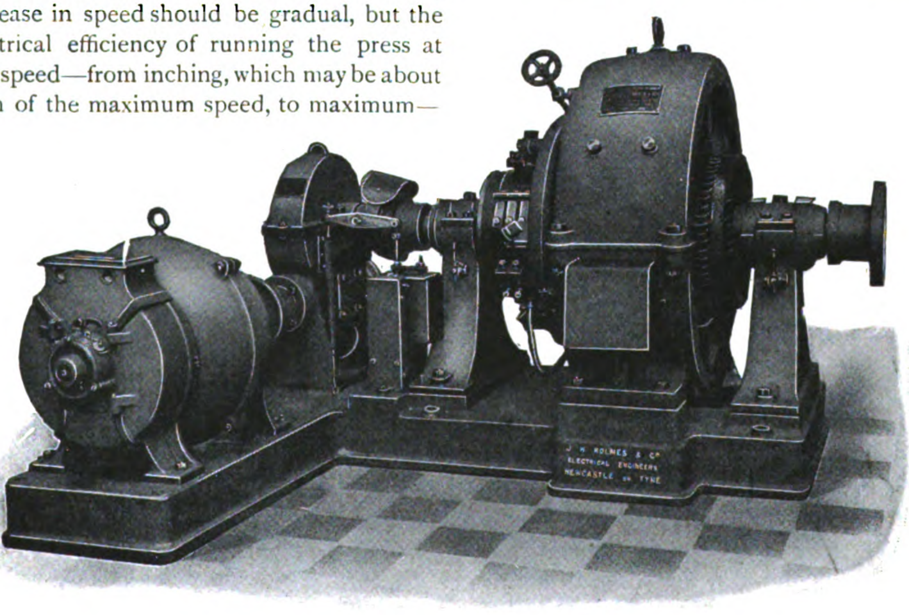


FIG. 12. HOLMES-CLATWORTHY MOTOR EQUIPMENT.

operating a motor geared on to the controller shaft, thus permitting the controller to be under entire control from any part of the press.

Figs. 13 and 14 show the construction of the controller, the action of which is as follows: On closing the main switch and turning the controller handle the two upper switches are closed by means of pawls fixed to the travelling crosshead; these switches are held in against the action of a spring by magnetism and at the same time the clutch solenoid on the small motor is energized and the small motor runs up to speed. When a certain speed has been reached the main motor switch, *i.e.*, the lowest one shown in Fig. 13, is closed, and the auxiliary motor single-pole switch opened, thus releasing the clutch and allowing the large motor to take up the load. Its speed is then gradually increased by cutting resistance out of the armature circuit and also inserting resistance into the field circuit when extra high speeds are required.

The Witton-James System.

It is claimed that this system is very economical on both low and high speeds, due in the former to a purely electrical drive without the use of worm-gearing or automatic clutches, and in the latter to a wide shunt field speed regulation on the main motor. The set consists of a main motor direct-geared to the press shaft; also an auxiliary motor direct-coupled to a low-voltage generator, forming a booster set. The method of operation is as follows:—The main switch, which is in series with a circuit-breaker, ammeter, and master controller, is closed, and the master-controller thus operated so that the booster set supplies current to the main motor at a low voltage, and a plating and sheeting speed variation is obtained from, say, 6r.p.m. to 18r.p.m. of the cylinder; this is effected by means of shunt field control of the generator only. On further operation of the master-controller, the speed is increased from sheeting to normal by cutting resistance out of the main motor armature circuit. From normal to maximum the increase in speed is effected by main-motor shunt field control. This may vary from 160 to 200 cylinder revolutions, according to the quality of paper in use. These various combinations of drive are obtained (*a*) by the operation of push-buttons, which are mounted in multiple around the press; (*b*) by means of a hand wheel on the master-controller.

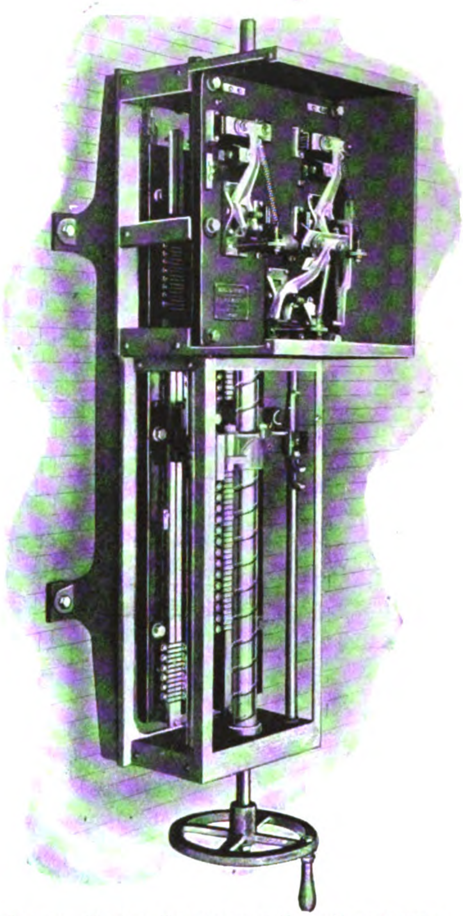


FIG. 13. HOLMES-CLATWORTHY HAND CONTROLLER.

(*a*) To work the press, having closed the main switch, it is only necessary to press any speed-up button to obtain a minimum speed, which, by use of the release-button, may be an inch or a continuous speed as desired. To accelerate gradually, the speed-up button has to be kept depressed until the desired speed is reached. To reduce the

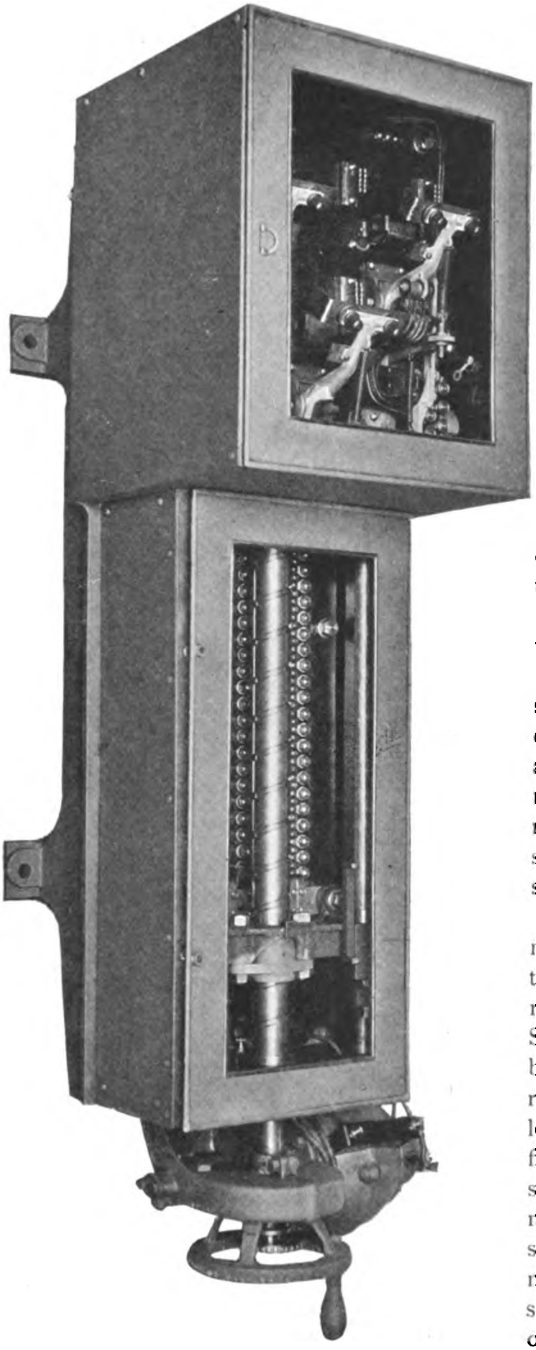


FIG. 14. MOTOR-DRIVEN HOLMES-CLATWORTHY CONTROLLER.

speed, the "speed-down" button is operated in the same way. Over or under speeding is impossible. To bring the press to rest the "release" button has to be depressed, when the whole can only be restarted at a lowest speed. When it is necessary to prevent the press being turned at all, it is only necessary to press any safety button, and until this has been released, all other buttons are out of action.

(*b*) When the controller hand-wheel is used, all movements of the press are governed by the action of turning the hand-wheel, as in the ordinary tramway controller.

In the case of two-ended presses it is quite simple to put the two sets in parallel for control purposes by use of paralleling switches, which put all circuits of the two sets in parallel, and enable control from any push-button box as one set.

Igranic System.

The controller in the case of the Igranic system of rotary printing press control more closely resembles the ordinary regulator in appearance, the set having only one main motor, and the control is effected by one rotary handle (illustration Fig. 15). The stopping is effected by operating the small switches shown.

The lowest speeds down to 10 per cent. of normal are obtained by means of an armature diverter resistance, *i.e.*, by inserting a resistance in parallel with the armature. Speeds from 75 per cent. to 25 per cent. below normal are obtained by a plain series-regulating resistance; from 25 per cent. below normal to normal by means of a series field diverter resistance; from normal to top speed, *i.e.*, two or three times normal, by means of shunt regulating steps. As will be seen from the illustration these various connections are made and broken by means of solenoid switches fitted with powerful blow-out magnets and carbon breaks.

The Kohler System.

This is one of the most recent methods which have been put on the market, and seems to be meeting with great success, there being over 500 sets running in America.

The motor drive consists of a main motor coupled direct to the press shaft, and an auxiliary motor driving on to this shaft through a worm gear and free wheel. The method of control is entirely automatic, and is operated by push-button stations, which can be placed anywhere on the press. The press is set in dead slow motion by pressing a small push button marked "run." By so doing a small solenoid at the back of the control board is energized and trips a ratchet pawl, allowing the plunger of a large solenoid to gradually descend by gravity, the action being retarded by means of a dashpot. As the plunger descends it cuts resistance out of the small motor circuit, which consequently speeds up the press. If this motion is allowed to continue till the motor is running at top speed, the large motor takes up the load and the small motor drops out of action. The plunger descends still further and cuts out the large motor armature resistance till normal running speed is obtained. If speeds above this are required the shunt field is weakened by inserting a resistance in the usual way.

If it is desired to prevent the acceleration of the press above a definite speed, a "safe" button is pushed in when that speed is attained, and it is then impossible to accelerate further, but the press can be slowed down or stopped entirely from any of the push-button stations.

If for any reason it is necessary to stop the press quickly in case of a broken paper web or for any such accident, a button marked "off" must be pushed. When the motor current is opened the main switch solenoids insert a brake resistance in the armature circuit, thus stopping the press in a few seconds. Whenever the press is stopped the controller returns automatically to the starting position. The overload and no-volt release contacts and solenoids are also mounted on the main control board.

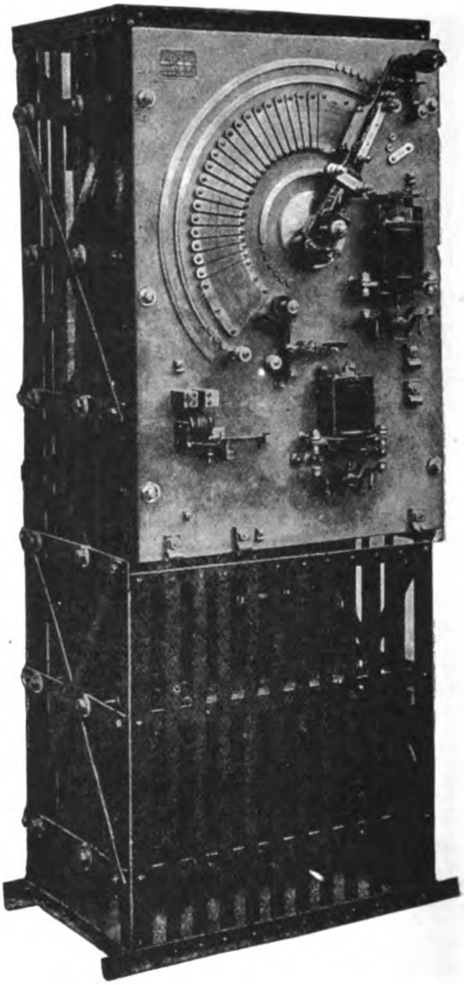


Fig. 15. The Igranic Controller.

When it is necessary to parallel the motors on two presses arranged end to end in order to run the presses and work together, as is sometimes convenient when an extra large issue is required, it is quite simply done by operating paralleling switches which put all resistances in parallel, likewise all push-buttons.

ELECTRICAL MEASURING AND TESTING INSTRUMENTS.

To the average man the term "electrical instruments" immediately brings to mind ammeters and voltmeters. However, a closer study of this highly specialised branch of the electrical engineering industry reveals the great diversity of indicating, measuring and recording devices required in present-day electrical practice. It is not intended in this article to deal with these instruments in even a general sense—space would not allow—but to describe briefly the newest developments which have been quite recently introduced by the leading British manufacturers.

The specialities of Messrs. Kelvin & James White, Ltd., are well known to every electrical engineer. Following the exacting requirements of modern practice, this firm has recently introduced many improvements into the various instruments of their manufacture.

Lord Kelvin's S.R. amperemeters and voltmeters for direct-current are of the dead-beat moving-coil type. The principle upon which their action depends was first used by Kelvin in the Siphon Recorder telegraph instrument, hence the name S.R. (siphon recorder) type. The workmanship and accuracy are of the same high-class nature that has always been the distinguishing feature of Kelvin's instruments.

Particular attention may be drawn to the fact that all shunts are adjusted to give the same volt drop at full load; this ensures that all shunts and instruments are interchangeable.

One improvement consists of making the case absolutely air-tight. This is effected by inserting a rubber packing in a groove in the base of the instrument. The instrument is also now provided with an external zero-adjusting device constructed in such a way that no damage can be done to the instrument by overshooting the maximum and minimum positions for the zeros. Further, the design of the instrument is now modified so that the movement is extremely accessible when the cover is removed.

The Kelvin mains insulation testing set remains in principle the same as heretofore. The improvements effected are such that it

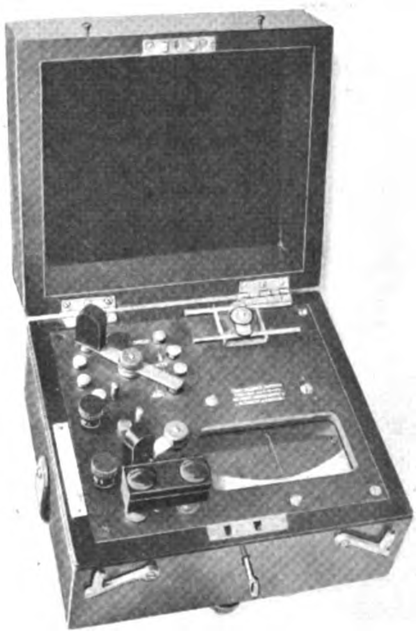


Fig. 1. The Kelvin & White Testing Set.

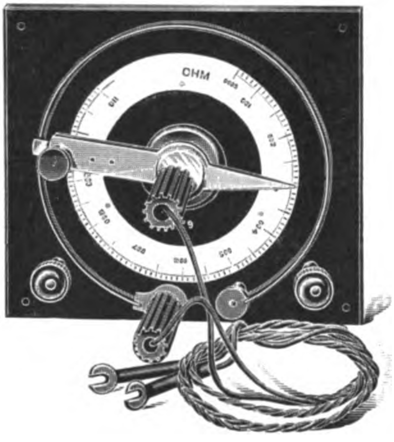


FIG. 2. FAULT LOCALISER.

is mechanically a better instrument than previously. The latest pattern is illustrated in Fig. 1. It is now quite dust-tight, and has been also improved in general appearance. A small fault localising bridge, Fig. 2, is also made for use in conjunction with this testing set. It consists of a wire of uniform resistance arranged in circular form on a vulcanite base, and a switch is provided so that contact can be made at any part of the wire. The latter is made either to have a resistance of 0.1 ohm or 1 ohm, and, as a scale of 100 divisions is provided, the value of each division is 0.0001 or 0.001 ohm respectively.

Kelvin's multicellular electrostatic voltmeters are so well known that a description of the instrument is unnecessary. They are operated by electrostatic forces only, and are, therefore, unaffected by temperature or external fields. Since they are independent of wave form and frequency, they are equally accurate on continuous and alternating current circuits. The amount of energy required to operate the electrostatic type of instrument is negligibly small. This, at times, is a very important property in accurate laboratory tests, and also in cases where it is advisable to limit the load on a potential transformer. Many improvements are embodied in the latest pattern, the most valuable having been rendered possible by connecting the movable vanes to the circuit through the medium of the liquid in the dash pot, instead of through the suspension. The pointer and scale are now insulated from the circuit and electrically connected to the case. They, therefore, do not require to be screened. The liquid now used, while conducting, has also very high resistance, which effectually prevents any damage to the moving system, due to a large flow of current, in the event of an accidental contact between the vanes and cells

The damping arrangement has been simplified. The dashpot is narrow and deep, and need only be about one-third full. It is therefore less liable to be spilled, and troubles due to varying depths of liquid are obviated.

All the essential parts of the instrument are supported by a single casting. These include the suspension, vanes, screens, pointer, scale, and, most important, the spirit level. This arrangement allows the movement, &c., to be removed from the case for examination, and replaced without disturbing the calibration or level.

The method of screening is much improved. The insulated tinfoil lining is now replaced by substantial metal screens, mounted on insulators. Further, the switch handle and packing screw are more accessible, and the zero adjusting device has been simplified; the terminals are now placed further apart, and no live parts are exposed.

The new portable form of this instrument is shown in Fig. 3. The switchboard type is now supported by means of a greatly improved form of bracket, as shown in Fig. 4, which permits the instrument to be drawn out horizontally instead of being lifted vertically. This is important, as no extra space above the instrument need be allowed on the switchboard panel.

The portable horizontal scale wattmeter manufactured by Messrs. Kelvin & James White, Ltd., is of the electro-dynamometer type, the coils being arranged astatically, thus annulling any effect due to external fields. The case of the instrument is made of a non-conducting material, which still

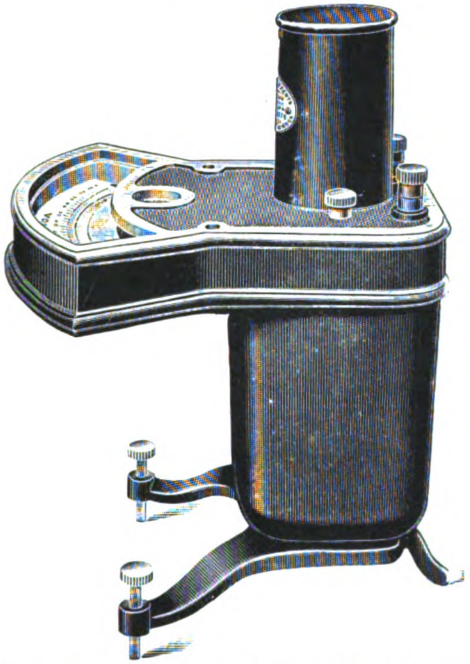


Fig. 3. Latest Pattern of Portable Form Kelvin's Multicellular Electrostatic Voltmeter.

further increases the accuracy, in that there is no error due to eddy currents. A further improvement, in the way of obtaining stability in the instrument, is the wooden base with which these wattmeters are now fitted.

A new type of revolutions recorder, Fig. 5, manufactured by this firm has been designed to meet the demand for an accurate graphic record of any revolving, reciprocating, or other periodic motion during any specified time. Primarily, the apparatus was constructed for the purpose of obtaining the correct speed records of propeller shafts of vessels during speed and power trials, but it can be adapted for counting the motions of a wide range of machinery.

The recorder consists of a number of pens which are electro-magnetically operated. The number of pens used depends upon the number of shafts, or other machines, of which records are required.

The electro-magnets are actuated by contacts fixed upon the revolving or reciprocating mechanisms, whilst the records are traced on a continuous band of paper, driven by a powerful clockwork arrangement, the speed of which can be regulated to give any desired speed of paper, from 2in. to 15in. per minute. The time record on the paper is effected by a separate pen and electric circuit connected to a standard clock This time-record shows the lapse of every half-second or some other greater interval of time. This arrangement renders the timing independent of the speed at which the paper is travelling.

In order to check the time in starting and stopping under certain conditions, and also for recording the distance and time elapsing between the passing of landmarks when making speed and power trials, a stop-watch can be connected to one of the pens and a mark made on the paper when this watch is started and stopped. This is again checked by the time record made by the standard clock.

Whilst the instrument is being used for the recording of the revolutions and speeds of the engine-shafts during trials, it can be used simultaneously for recording the performance of the auxiliary pumps, fans, &c.

On reference to Fig. 6 it will be noted that there is a break in the record at every tenth impulse of the standard clocks. This greatly facilitates the counting up of the

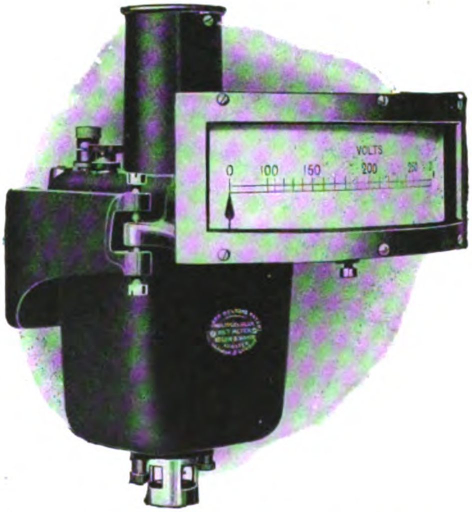


Fig. 4. Latest Pattern of Switchboard Form Kelvin's Multicellular Electrostatic Voltmeter

total time of run, especially when this extends over a considerable period.

For recording extremely rapid movements a tuning fork operated electrically can be used for giving the time record, instead of the standard clocks illustrated.

Without an instrument such as just described, it is necessary to have a separate observer at the counting dials of each engine, who reads the number of revolutions during a specified period. It is possible to obtain fairly accurate results by this means, but there is always a liability to personal errors. To obtain the speeds of several shafts at the same specified instant requires as many skilled observers as there are shafts; even assuming the absolute accuracy of each observer, dependence must be placed upon a speed indicator or tachometer. The instrument described above does not in any way depend upon the skill, or the personal equation in reading, of one or more men; but, when once properly connected, it can be looked after by one man only, and the records obtained are certain to be correct. Further, the records are permanent; they can be read at leisure after the tests are over, and can be kept for reference in case of any controversy afterwards arising.

Messrs. J. J. Griffin & Sons, Ltd., are now supplying an improved form of quartz glass mercury lamp, suitable for scientific research. The lamp is illustrated in Fig. 7, and will be seen to consist of three distinct parts: the anode bulb, the cathode bulb, and the vapour tube. The anode and cathode bulbs are different both as to size and shape. The sizes are as far as possible proportional to the amount of heat developed at the respective poles, in order that the loss of heat at each end may be proportional to the heat generated. This is necessary if vapour is to be produced at the same rate at both electrodes, so that it may be possible for the lamp to burn continuously.

Since it is never possible to obtain the precise proportionality required between the sizes of the two bulbs, an additional device

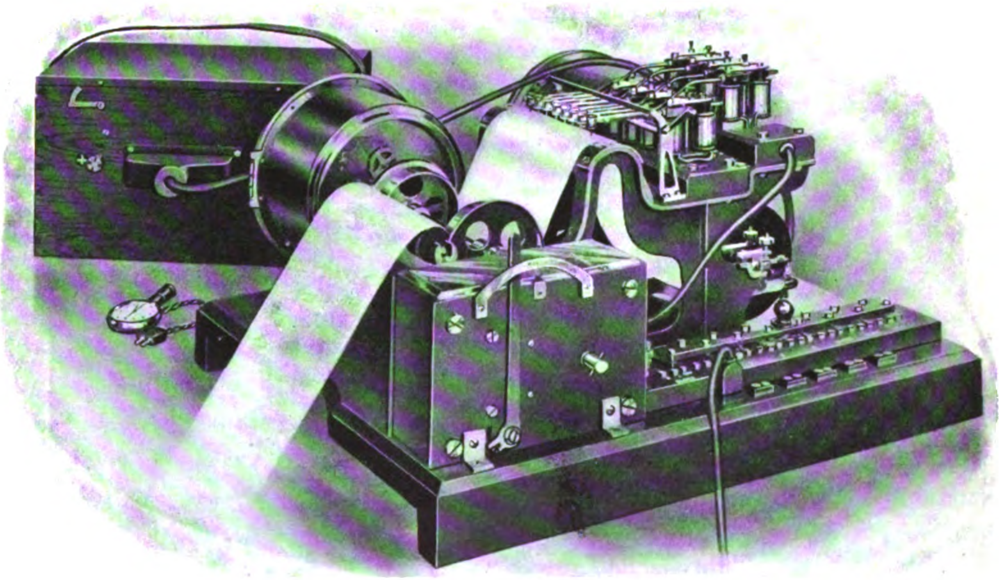


FIG. 5. REVOLUTIONS-RECORDER.

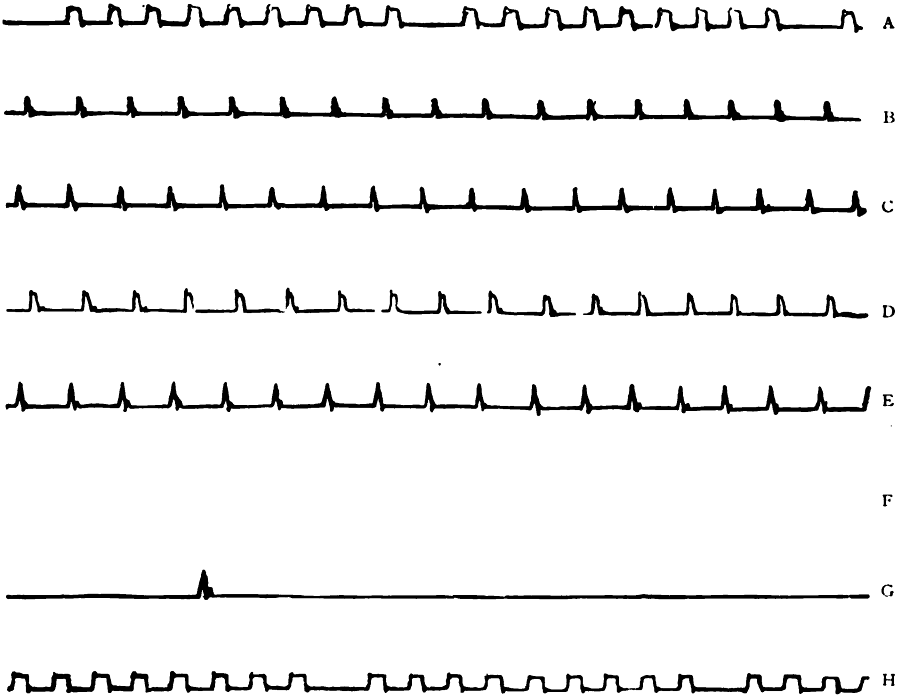


Fig. 6.

A.—Standard clock impulse every half-second.
B.—Port outer; C.—Port inner; D.—Starboard inner; E.—Starboard outer. Shaft's impulse every two revolutions.
F.—Spare pen.
G.—Bridge time signal.
H.—Spare standard clock.

has been employed to establish automatically a balance between the heat generated and the heat radiated. This device consists in drawing out the cathode bulb into a narrow neck where it joins the vapour tube. The bulb and part of this neck is filled with mercury. The heat developed at the surface of the mercury is carried away by the mixing of the hot metal with the colder contents of the bulb; the wider the neck and the nearer the surface of the mercury is to the bulb, the more rapidly will this transference of heat be effected. If at any instant the heat is carried away too rapidly the mercury level in the neck will rise, and this will tend to retard the flow of heat to the bulb. By sufficiently contracting the neck and by making the cathode bulb of a suitable size, it has been possible to produce a lamp which burns for any length of time. The electrical qualities of the lamp are dependent upon the amount of vapour produced at the electrodes. Other things being equal, this will depend upon the cooling of the electrodes; the better they are cooled, the greater will be the current through the lamp. In order, therefore, to make the smaller model capable of absorbing a greater amount of energy, the bulbs are surrounded by metal bands carrying radiators.

The lamp is started by lifting the handle and tilting it until a continuous thread of mercury extends from the positive to the negative pole. The arc is struck by the rupture of this thread, after which the lamp is lowered back into its original position, and the excess mercury returns to the positive pole.

On a 220-volt supply with a regulating resistance of about 50 ohms in circuit the

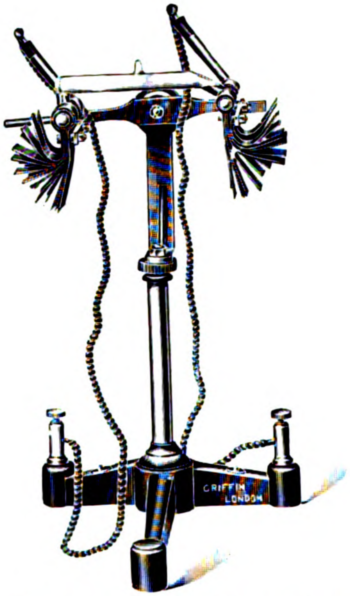


Fig. 7. Quartz Glass Mercury Lamp.

lamp can be made to burn continuously with any P.D. between its terminals varying from 25 to 175 volts. At low voltages the arc fills the entire cross-section of the tube, whilst at higher voltages it becomes more and more constricted and ultimately forms a thread having a thickness of about 5mm. The light yielded by this lamp is the greatest which has ever been obtained. Thus with 304 volts between the terminals and a current of 3.85amp. about 6420c.p. were developed, which corresponds to an expenditure of 0.182 watt per c.p. In order, however, not to prejudice the life of the lamp, it is usually not run at a higher pressure than 175 volts. Then it consumes 4amp. and develops a mean spherical c.p. of about 2860, which is equivalent to 0.244 watt per c.p.

It is well known that the mercury lamp is very rich in ultra-violet rays, also that quartz glass is transparent to such rays. This lamp, indeed, is by far the richest available source for actinic rays of short wave length, and, as such, may be usefully employed for photo-mechanical purposes.

These lamps are also made for use on a 110-volt supply.

Messrs. Griffin are also supplying a lamp in which a liquid amalgam replaces the mercury. This lamp yields an extraordinarily rich line spectrum. The amalgam—introduced at the suggestion of Dr. L. Arons—consists of *about* 60 per cent. mercury, 20 per cent. lead, 20 per cent. bismuth, ½ per cent. zinc, and ½ per cent. cadmium. At about 125 volts the whole arc exhibits line spectra, particularly rich in the ultra-violet region, of all the five metals.

The electrical qualities of the amalgam lamp are the same as those of the mercury lamp.

The electrical measuring instruments supplied by Messrs. Everett Edgcumbe & Co. are already well known, and, judging by the new and improved types we have examined, these are likely to maintain the firm's prominent position in this kind of work. They are now making switchboard recorders in which the record is marked on a flat chart of circular form. Fig. 8 illustrates this class of instrument. The hours are marked round the circumference, and the circles represent the scale divisions (volts, amperes, watts, &c.). A unique feature is that the window in the front displays the

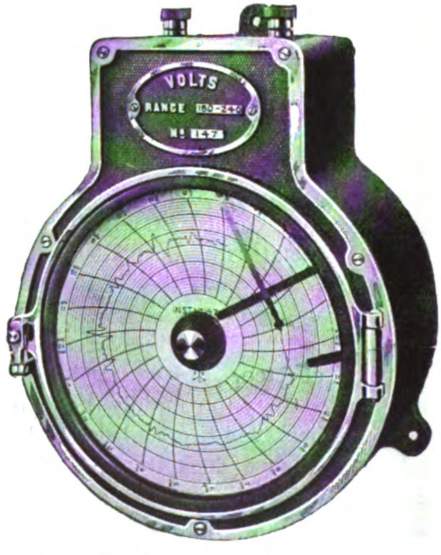


Fig. 8. The Everett-Edgcumbe Recording Voltmeter.

whole of the chart, so that the complete record can be seen at once.

The pen mechanism is also of an improved pattern and gives a uniformly perfect record without attention or adjustment. The form of pen adopted is a sort of V-shaped tooth. The ink is well closed in, but, at the same time, the pen is easily filled, owing to the fact that it is open on the side nearest to the operator, and, for the same reason, is readily cleaned. The fact that these pens give an equally perfect trace with speeds as low as 2in. per *day* and as high as 12in. per *minute*, with drum-type instruments, where the conditions are less favourable than with flat disc charts, is the best criterion of the correctness of their design. Further, the arm which carries the pen is extremely flexible, so much so, in fact, that it can be almost doubled back on itself without harm, thus considerably minimising any risk of damage through rough handling, and at the same time giving a light and constant pressure on the chart.

The circular chart is carried on a metal plate which is driven by the clock through a friction clutch so that the chart may be set to the correct time without producing any strain on the mechanism. A special catch-arm—shown nearly radially in Fig. 8—is provided, so that when the case is opened, in order to change the charge, the pen is automatically lifted free of the latter out of danger of damage during the process of chart changing. On closing the case again, the index is free to take up its natural position.

These disc recorders are furnished with "one-day" clocks, driving the charts at mid-scale speeds of ½in. or 1in. per hour for 24 or 12 hours respectively. The latter type is especially for factory use when the plant is shut down at night.

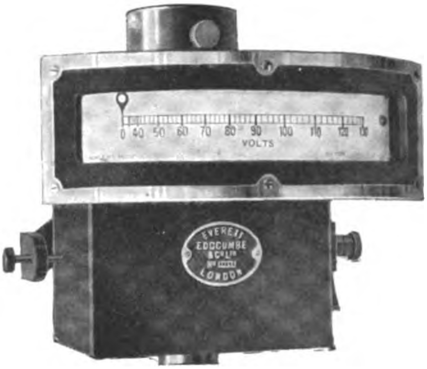


FIG. 9. HAMILTON ELECTROSTATIC VOLTMETER.

In order to facilitate re-charting in the drum form of switchboard recorder, the drums are frequently so arranged as to hinge or slide downwards, clear of the pen, so that when space is limited, a recorder of the Everett-Edgcumbe "disc" pattern proves extremely suitable. In America, similar recorders, due to Professor Bristol, have been used for some years.

One of the latest forms of electrostatic voltmeters—that due to Hamilton—is made by this firm, and is illustrated in Fig. 9. It is of the low-tension pattern, and the working portion is enclosed in a complete metallic case, from which it is insulated, the case being provided with means for earthing, affording absolute protection from static shock should the instrument be handled. It is claimed that this is a particular advantage which the Hamilton patent possesses over all other electrostatic voltmeters on the market.

(*To be continued.*)

THE WORLD'S ELECTRIC PROGRESS.

Petrol Electric Generators.

THE general user of electricity must rapidly be coming to the opinion that the machines and appliances employed both in the generation and utilisation of the power have been considerably improved within the space of a few years. The electric lighting of buildings remote from public supply mains had come to be considered as a refinement of luxury, limited to the country properties of the wealthy. Installations of this character were of high first cost, their upkeep was expensive, and they were usually not of high efficiency. Yet this branch of the electrical business offers a wide and attractive field to the manufacturer, and the special work of designers towards securing small electric power generators which should be efficient as well as independent of constant skilled attendance has evolved lines of gas, oil, and petrol-engine sets which combine low cost with every degree of reliability. In large towns of course it is practically always advisable to buy current from the public supply authorities; but in the case of isolated buildings, such as country houses, and remote workshops, laundries, factories, &c., a self-contained electric plant is of extreme value. The recent progress made in the design of petrol engines mainly for motor-car purposes has led to the combination set of an electric dynamo coupled to a small petrol engine which has proved extremely efficient. Of this class of generator the "Sanco" petrol electric set exhibits a remarkable simplicity of construction which ensures uniformly successful operation in the hands of unskilled labour.

The engine is designed on what is known as the two-stroke principle; that is, the crank shaft receives an impulse every revolution,

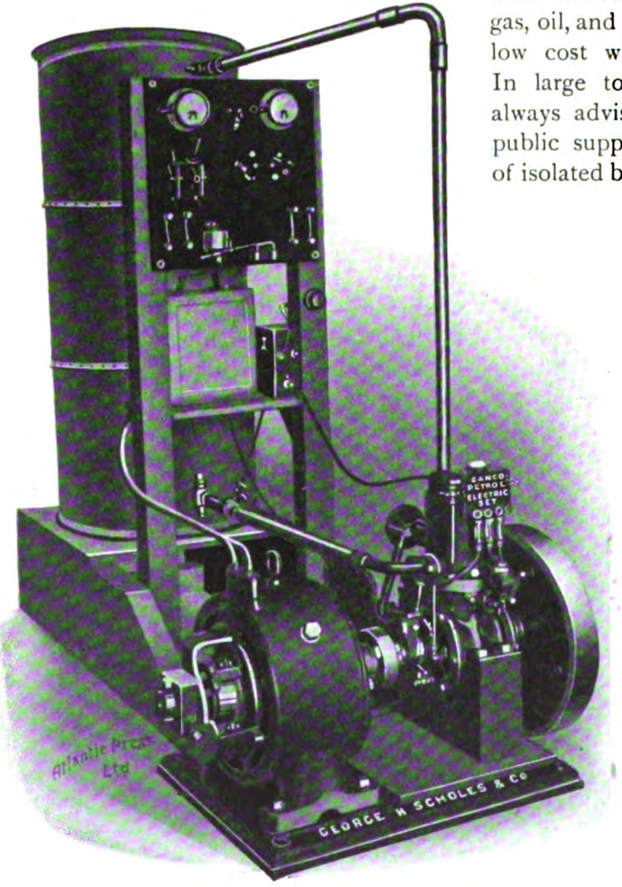


FIG I. THE "SANCO" PETROL-ELECTRIC LIGHTING PLANT COMPLETE.

which gives a very even turning movement, and the steady running which is of considerable advantage in connection with electrical work. It is extremely simple, there being only three working parts, viz., piston, connecting rod, and crank shaft. These parts are carefully counterbalanced, thereby eliminating vibration as much as possible. All the bearings are of ample size, and are made of phosphor bronze. There are no valves exposed to the extreme temperature of the burning gases, the admission of the explosive mixture, and egress of the products of combustion being controlled by the piston covering and uncovering two ports in the cylinder. Each engine is fitted with a patent system of exhaust scavenging which is extremely simple and at the same time effective. The method of operation is as follows: An intermediate chamber is provided between the crank case and cylinder, and at each revolution of the engine this chamber is filled with pure air, which enters the cylinder under pressure immediately after each explosion, and effectually sweeps out the burnt gases before the new charge of explosive mixture enters. This effects a considerable economy of fuel. Special attention has been paid to the lubrication of the engine, and the oil is fed under pressure through sight feeds. The pressure is obtained from the under side of the cylinder, and not from the exhaust, as is common; by reason of this arrangement the tubes do not become choked by burnt carbon.

The dynamo is of the four-pole type, shunt wound, and capable of efficiently supplying its full rated load for long periods. The commutator and brush gear is of large size, giving ample contact surface and sparkless running. The dynamo is assembled on the same base-plate as the engine to which it is direct coupled. The complete "Sanco"

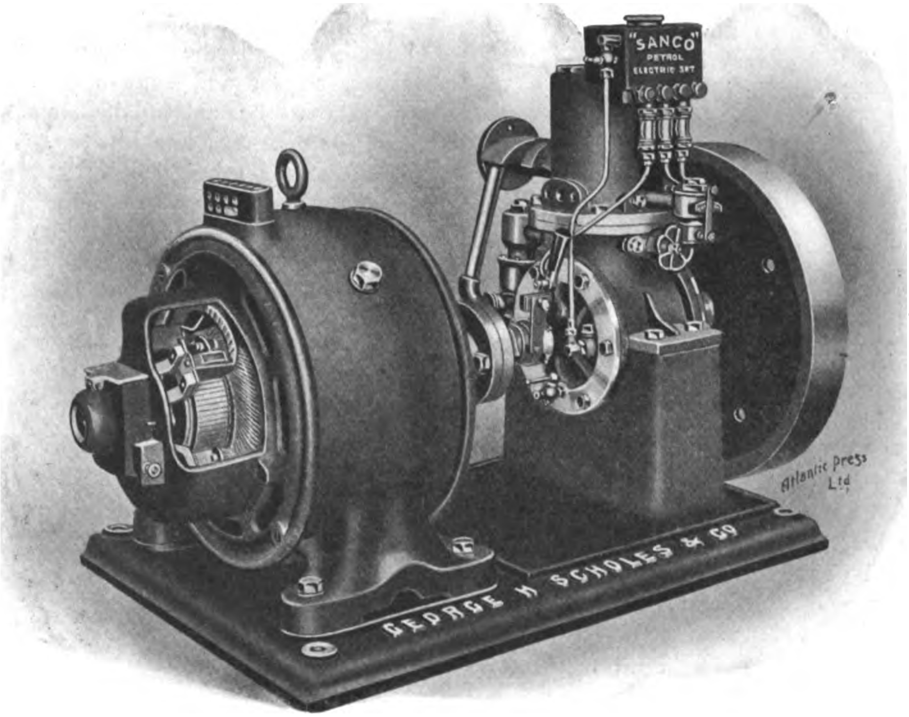


Fig. 2. Engine and Dynamo of "Sanco" Electric Lighting Plant.

set as made by Messrs. G. H. Scholes & Co., Manchester, comprises the engine, dynamo, sparking coil, set of batteries, switchboard, water-cooling tank, and petrol tank, and is standardised in two sizes, one for 50 lights, and the other for 100 lights.

❧

Plating on Aluminium.

A PROCESS of electrodeposition has recently been patented which promises to be of considerable commercial importance. Solutions of metallic salts in water are the rule in electroplating, although in special cases, where the desired deposit would react with water, it has been suggested to employ other solvents than water. The new process embodies the use of a plating bath, consisting of a solution of a chloride of the metal to be deposited in alcohol. The alcohol may be either commercial ethyalcohol or methylalcohol or denatured alcohol. The chief advantage desired is the practical suppression of the evolution of hydrogen gas on the surface to be plated. The electrolyte may be made by dissolving the metal chloride in the alcohol. Another way is to add one or several per cent. of pure concentrated hydrochloric acid to commercial alcohol and start electrolysis with an anode of the metal to be plated, whereby the metal chloride is produced by anodic reaction. It is stated that in this way, at ordinary temperature and without any further additions, an excellent electrolyte is formed for depositing gold, copper, nickel, cobalt, tin, and other metals. From 2½ to 3 volts are said to be required. The process is not applicable for plating with silver and lead, and is not recommended for plating with platinum and zinc. It is claimed that alloys (like brass) can be easily deposited by this method either by dissolving a mixture of various metallic chlorides in alcohol or by employing anodes made of different metals. Zinc, nickel, copper, and tin may form a variety of colours on the same cathode. Alloys of other metals with aluminium (though not pure aluminium) may also be deposited. The process is said to solve in an easy way the problem of plating other metals upon aluminium. The trouble in plating aluminium has always been supposed to be due to the invisible film of aluminium oxide, which always exists on aluminium surfaces, and which prevents other metals from sticking. If the aluminium surface to be plated is first made anode in the alcohol plating bath the oxide film is reduced within a few minutes, and when then the connections are reversed and the aluminium surface is made cathode, the oxide film does not form again in the alcohol solution and the electrodeposited metal strikes upon the clean pure aluminium and adheres to it.

❧

"Victor" Arc Lamps.

THE well-known "Victor" Arc Lamps, manufactured by the Electric and Ordnance Accessories Company, Ltd., include ordinary standard enclosed and a special form of miniature enclosed and also flame arc lamps. The chief feature in these lamps is the device used to produce a regular and smooth feed to the arc without the aid of the shunt coils, cams, levers, &c., which are so much in evidence in other lamps. The device used is known as the "Victor" clutch, Fig. 1,

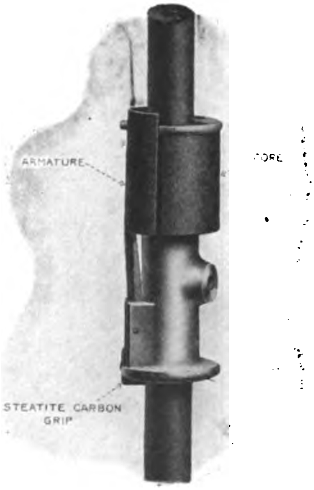


FIG. 1. THE "VICTOR" CLUTCH.

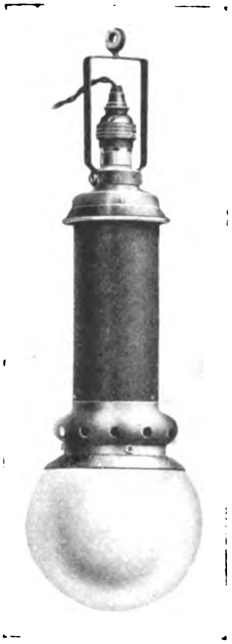


FIG. 2. "VICTOR" MINIATURE LAMP.

and works on the magnetic principle. This clutch consists essentially of two parts—a core and armature, the armature being pivoted and provided at one end with a steatite grip, so that the carbon passing through the core is gripped by the latter when the current is switched on, and at the same time the whole clutch is drawn up, seeking to take a balancing position in the air gap formed between the end of the series magnet core and the magnet frame. The whole device is extremely simple and efficient. All the lamps are fitted with this clutch, which is, moreover, essentially the only moving part in the lamps, all other clockwork devices, shunt coils, &c., having been proved unnecessary.

The standard enclosed lamps will operate singly on 100-125 volts, this being a considerably higher voltage than that usually employed, effecting a great saving in current and a considerably enhanced efficiency as compared with lamps working on the same voltage but which use a large line resistance. The carbons used are each 11mm. in diameter, and are solid, the difference between the positive and negative carbons being only in that of length. These lamps are also made for photographic use, and can be fitted with special inverted reflectors for use in drawing offices, factories, &c., where absolute diffusion of light is necessary.

The miniature enclosed lamps, Fig. 2, are constructed practically the same as the standard type lamps, but are of course much smaller, their size being only about 16in. long over all, and weight about 4lb. These lamps are specially adapted for lighting stores, warehouses, shops, &c., where formerly clusters of incandescent lamps have been used. The efficiency of these lamps is remarkable, running to about 1 watt per candle-power, the candle power being approximately 350. For indoor use the lamps are provided with a special bayonet type adaptor and plug, and can be run on ordinary incandescent lighting mains, the current running to only about 1½ to 2½amp. according to whether the lamps are run singly on 100 to 150 volts

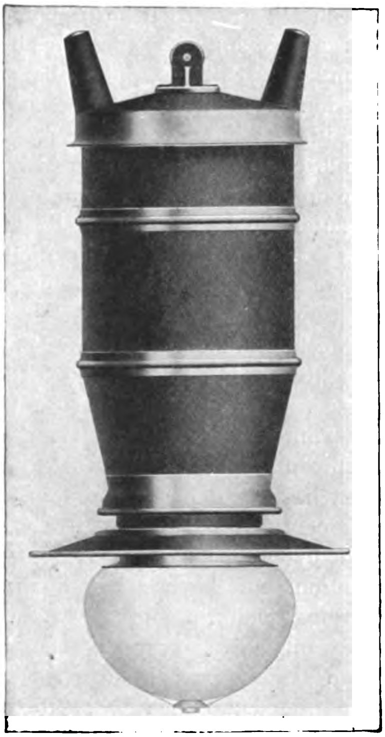


FIG. 3. "VICTOR" FLAME LAMP.

or two in series on 200 to 250 volts. Burning-hours with one pair of carbons are approximately 30 to 40. The lamp is simple to trim, it being only necessary to take the globe off—this by special design being an easy operation.

In the flame lamps, Fig. 3, the carbons are inclined to each other, and each is fitted with one of the "Victor" clutches. The carbons strike off an insulated heat-resisting roller. Both carbons are cored and the same length, the positive being 9mm. diameter and the negative 8mm. With one pair of carbons the burning-hours are approximately 18 to 20, and the candle-power averages 2500 to 2750. The lamps take from 6amp. to 8amp., and run singly on circuits from 80 to 120 volts with very little line resistance.

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Electric Laundries.

In the modern laundry electricity is widely used in lamps, motors, and heaters, in all of which it has demonstrated its convenience and cleanliness. The light in a laundry must be good, particularly when work is done at night or when the laundry is situated in a sub-basement, as often occurs in the laundries of large hotels and institutions or those on passenger steamers and warships, which latter are located in the hold, where daylight does not penetrate. The walls and ceiling are generally finished in white, and in the most up-to-date laundries, the large commercial establishments and those of hotels and institutions, white enamelled tiles are often used. On shipboard the use of white enamel paint is advantageous. In the older establishments white paint is now used with a liberal hand, and has resulted in a great improvement of the interiors. Arc lamps are occasionally used in laundries for general illumination, but they are best adapted for the loading platform and the yard. The incandescent lamps, owing to the fact that they can be obtained in units of various sizes and the lamps can be so distributed that shadows are avoided, are usually employed for the interiors. Nernst or metal-filament lamps can be used with great advantage and installed to suit the various machines. No general rule can be given for the distribution of these lamps, but it is desirable to have an intensity of illumination of from 7 to 10 foot-candles on the machines and at points where the goods are handled. This intense light is necessary owing to the fact that each article must be carefully inspected after each operation in order that imperfect work can be detected and turned back.

The individual motor drive, except on the finishing tables and possibly on the washing machines, is the most satisfactory method of handling the motor problem in laundries, although the group drive can be utilised for some machines. The use of motors eliminates the overhead shafting and belts, which are the source of a great deal of trouble, and from the view-point of the laundry proprietor this trouble is a serious matter. Overhead shafts and belts accumulate dust and dirt, and on occasions the drip pans for the bearings overflow and a considerable portion of the laundry work must often be handled twice from this cause. Laundry operations are intermittent; many of the machines are used only at intervals and others are in operation during only a portion of the working period; hence it can be appreciated that a considerable economy can be effected by a motor installation which only consumes power during the actual period of service. The motors required for this work are of comparatively small sizes, but there are a great many laundries, and their number is increasing, and for this reason the field offers great opportunities to the motor manufacturers who study its requirements. The character of the work is such that at the present day the direct-current motor is best suited for laundry service owing to the facility with which its speed can be controlled.

Washing machines are usually installed in the basement or on the first floor. These machines are generally rated by the number of shirts washed at a time and are built for from 40 to 400 shirts; they require to be installed upon a concrete floor arranged with drains for disposing of the water from the machines and for handling the wet goods removed from them. The extractors for drying the goods are usually placed in front of the washers in order to concentrate the sloppy portion of the work in one place. The washing machines consist of two concentric cylinders, the outer is water-tight and stationary, while the inner is perforated and arranged to revolve, in which the goods to be washed are placed. When the goods are put in the machine cold water is admitted and the machine started, live steam being then admitted. The individual motor drive is occasionally used for washing machines, but the group drive is generally favoured. The inner cylinder revolves first in one direction, then in the other, and the reversing process consumes considerable energy. With the group drive the motor will be smaller than the aggregate power of the motors required for the individual drive. In addition, the motor driving a group of washing machines can be so placed that it will not be subjected to the dangers of having water splashed over it. Chains are often used for transmitting the power from the motors to the line-shafts, and waterproof leather or rubber beltings are used between the line-shaft and the washers. Some washing machines are driven by a single belt with a geared reversing mechanism, and this method has proved satisfactory. This geared device is desirable when individually driven washing machines are used, but the belt drive is often employed.

With regard to the determination of power required by washing machines, a rule-of-thumb method is to allow 1.50h.p. per 100-shirt rating of the washing machines for the individual drive and 1.25h.p. per 100 shirts for the group drive. This rule works out very well in practice and gives ample power for the reversing mechanism. With the group drive this rule allows for the power in the line-shaft. The motors employed are usually of the compound-wound type.

The extractors, sometimes called hydro-extractors or centrifugals, are driven by series motors. For laundry work the extractors range from 20in. to 30in. in diameter of basket and run at a peripheral speed of from 5000ft. to 6000ft. per minute. These machines are used for a few minutes at a time and then are idle while the dried goods are removed and a wet batch placed in them. A rheostat and a double-pole switch are used for control purposes. The rheostat can be mounted on the curb of the extractor or upon a convenient post or on the motor pedestal, if one is used. There are several methods of applying the motor drive to extractors. According to the earliest type, the motor was mounted on a pedestal behind the extractor and drove the extractor through a quarter-turn belt. A later type of drive uses a vertical-shaft motor mounted upon an extension of the extractor bedplate and belted direct to the basket spindle. In the latest type of motor-driven extractor the motor is combined with the machine, the armature of the motor being mounted directly upon the spindle of the machine.

Tumblers are used to shake the goods out after they are removed from the extractors. These machines are similar to washing machines; they require about the same amount of power as does a washing machine of equal size.

Mangles are made in a number of sizes, the smallest for handkerchiefs, the largest for heavy linens, damasks, &c. These machines require a controller giving one or two slow reverse speeds, and varying the speeds for the working direction from 50 to 125 per cent. of the normal motor speed by a combination of armature resistance and weakening the shunt-field current. Occasionally these controllers are equipped with an overload release, which is convenient in case the goods become stuck in the machine, as it prevents their being damaged. Mangles usually have from one to three heated rolls, although in some types there are one heated roll and four steam chests. The largest sizes handle work fed to them very wet in

Machine.	H.P. of motor.	Approximate speed of motor, r.p.m.	Kind of motor	Controlling device.
20in. hydro extractor	1.5	1400	Series	Starting box
26in. extractor	3.0	1400	Series	Starting box
30in. extractor	4.0	1200	Series	Starting box
Mangle, 120in.—				
Small, 3 rolls	1.0	900	Shunt	Variable speed Control with reverse speeds One or two slow reverse speeds Working speeds from 50 to 125 per cent. of normal
Small, 5 rolls	1.34	1200	Shunt	
Medium, 3 rolls	1.5	900	Shunt	
Medium, 5 rolls	2.0	1200	Shunt	
Large, 3 rolls	2.0	450	Shunt	
Large, 5 rolls	3.0	650	Shunt	
Handkerchief mangle	0.34	1200	Shunt	Variable speed Armature and field resistance
Return apron mangle	0.75	750	Shunt	
Single roll mangle	0.25	750	Shunt	Speed regulator
Small mangle, 4 rolls	0.75	750	Shunt	Variable speed
Bosom starcher	0.25	1000	Shunt	Starting box
Band starcher	0.125	1000	Shunt	Switch
Shirt starcher	0.25	1000	Shunt	Switch
Dip wheel starcher	0.50	600	Shunt	Starting box
C. & C. starcher	0.25	500	Shunt	Switch
Starch extractor	1.00	800	Series	Starting box
Cabinet dry room and conveyor dry room fans	0.25	200	Shunt	Switch
Dry room conveyor—				
2 loop	0.125	350	Shunt	Speed regulator
2½ loop	0.125	350	Shunt	Speed regulator
3 loop	0.25	450	Shunt	Speed regulator
3½ loop	0.25	450	Shunt	Speed regulator
4 loop	0.25	450	Shunt	Speed regulator
4½ loop	0.34	700	Shunt	Speed regulator
5 loop	0.34	700	Shunt	Speed regulator
C. & C. dampener	0.17	1000	Shunt	Starting box
C. & C. ironer, 42in.	0.75	750	Shunt	Variable speed
C. & C. ironer, 48in.	0.75	750	Shunt	Speed regulator
C. & C. ironer, 24in.	0.25	750	Shunt	Speed regulator
Combined ironer, 18in.	0.25	750		
Bosom ironer, 17in.	0.34	700	Shunt	Speed regulator Reversing switch
Bosom ironer, 10in.	0.25	1000	Shunt	Reversing switch
Bosom press	0.50	1100	Series	Reversing switch
Reverse body ironer	0.50	600	Compound	Speed regulator Reversing switch
Body ironer, 36in.	0.34	650	Compound	Speed regulator
Reverse sleeve ironer, 18in.	0.25	1000	Compound	Speed regulator Reversing switch
Sleeve ironer, 12in.	0.25	1000	Shunt	Speed regulator
Band ironer, 6in.	0.125	1000	Shunt	Switch
Cuff attached ironer	0.25	1000	Compound	Speed regulator
Fluting machine	0.125	1000	Shunt	Switch

Speed Regulator.—Denotes speed regulation by the insertion of resistance in series with the armature of the motor.

Variable Speed.—Denotes speed regulation from 50 to 125 per cent. of normal by the use of resistance in series in the armature circuits for the low speed, and by resistance in series with the shunt-field winding for the high speeds.

Starting Box.—Denotes the ordinary rheostat used with a shunt motor.

In the laundry many of the operations are intermittent, and the electrically driven machine consumes power only during the time it is actually in operation. Reliable data in regard to the cost of electrical operation as compared with mechanical operation are difficult to obtain. Few laundries care to disclose their cost of operation. It has been claimed

that the cost of operation was reduced by as much as one-third by the use of motors, while smaller reduction has been admitted in a few cases. Necessarily the size of the laundry will have some effect upon the reduction in operating expense, it being possible to obtain better results in a large plant than in a small one. In fact, the small plant may not save any expense for energy and may find its operation bill higher. It will make considerable difference whether energy is generated upon the premises or bought from a central station. High-pressure steam is necessary for heating the mangles and the washing machines, as well as for the dry rooms; owing to the necessity for a steam boiler for this purpose the generation of electricity either by steam-engine driven or gas-engine driven generators adds comparatively little to the operating expense. The elimination of dirty belts and shafting and the added convenience of the electric drive are factors of no mean magnitude On these grounds alone considerable expense in first cost of electric plant will be justified.

order that a snow-white finish may be obtained, and the figures on damask will show up raised. The work is conveyed through the machine by an apron, special feed guards being used in order to prevent the operators from getting their hands drawn in by the goods. The motors for mangles range in rating from 0.3h.p. to 3.0h.p.

Starching machines are made in a variety of types for handling different kinds of goods. Collars and cuffs are starched either in drum machines, which dip the goods under the starch and wipe off the surplus, or in a barrel or dip-wheel starcher, which consists of a vessel in which the starch and the goods are placed, the machine working the starch thoroughly into the fabric by rotation. A shirt starcher consists of a starch vessel and rubbing frames which work the starch into the fabric by a reciprocating motion. Bosom starchers are designed to apply the starch to the bosoms of stiff shirts, leaving the rest of the garment free from starch. These machines are used in combination with band starchers, which are employed for working the starch into the neck bands and the sleeve bands. These machines are also used in applying starch to attached cuffs and collars. The motors required for these machines range from 0.125h.p. to 0.5h.p. A regular starting rheostat is required, as the speed of the motor is not varied. Starch extractors are similar to hydro-extractors, but are run at slower speeds. The speed is adjusted to leave just the proper amount of starch in the goods. Series motors are used with these machines.

Dry rooms are of two types, cabinet dry rooms and conveyor dry rooms. In the former the goods are hung on racks and the air is circulated by means of fans, which require from 0.125h.p. to 0.25h.p. The conveyor dry rooms are made in a variety of sizes, ranging from two to five loops of the conveyor, fans being used to circulate the air. The motors for this work are of slow-speed type, and speed regulators are used for controlling the speed of the conveyors.

A variety of ironing machines are built for handling collars and cuffs, bosom ironers for shirts, body ironers for shirt bodies, band ironers for sleeve and neck bands. The latest step in the ironing is the use of presses instead of the ironers. The finishing table, which is a device in which collars and cuffs are finished on the edges and in which turn-over collars are formed, is also motor-driven. The motors used for these machines range in rating from 0.125h.p. to 0.75h.p., and a variety of controlling devices are used. Most of the motors are designed for comparatively slow speeds.

One of the great advantages of the motor drive lies in the fact that the speed of the machine can be accurately adjusted to turn out the maximum quantity of work. The increase in output varies largely, less advantage in this line being attainable in a well-managed plant than in one where the supervision is slack. Increases of from 50 to 100 per cent. in output have been attained by an intelligent study of the work when motor-driven machines were introduced. In some cases much greater increases in output have been secured, but only a portion of such gain is due to the use of motors.

In regard to the cost of equipping a laundry with motors, a writer in *The Electrical World* gives as an approximation that the cost can be estimated when the sizes of the motors are those suited for the ordinary commercial line of work by multiplying the aggregate horse-power required to operate the various machines by £33 ($160). This product will be the cost of the motors for individual motor drives and controlling apparatus. The preceding table is also given. This is based upon practical work and gives the rating and speed of the motors required, together with the type of controlling devices used for the equipment of laundry machinery.

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Slow-speed Fan Motors.

THE manufacturers of the well-known "Cyclone" fans and blowers, Matthews & Yates, Ltd., have just put upon the market their new motor as per illustration. The motor is specially designed for slow speeds, and is, therefore, eminently suitable for coupling direct to fans. It has a circular yoke, and when required to work as an independent motor, it can be fitted with feet, Fig. 1. The frame is made from a special mixture of cast iron, bored and machined to receive the laminated poles and bearing housings. The bearings are of the self-oiling type, fitted with long gun-metal bushes, and the lubrication is accomplished by two rings running in an oil well. Each bearing is interchangeable, and can be turned round to any quarter, thus allowing a standard machine to be fixed either on the floor, wall, or ceiling by simply turning the bearing round as required.

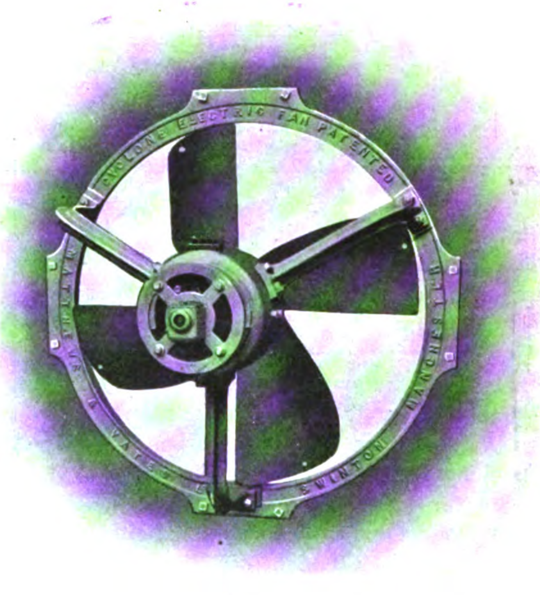

FIG. 2. SLOW-SPEED MOTOR FITTED TO PROPELLER FAN.

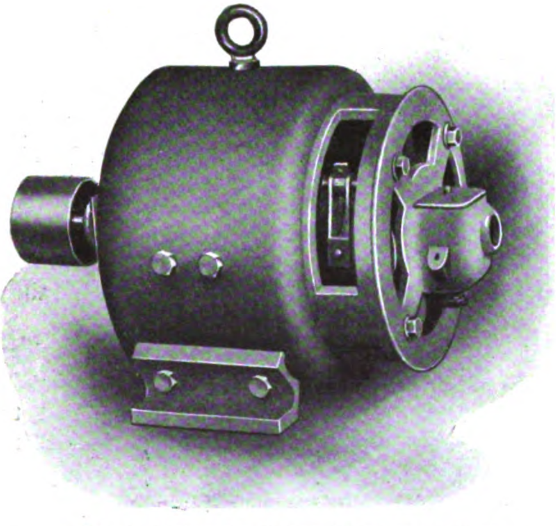

FIG. 1. SLOW-SPEED MOTOR, MATTHEWS & YATES.

The windings are formed before assembling, and each armature coil is taped and jigged before being laid in the slots. The end winding is symmetrical and secured to a cast-iron end-plate on both the two and four pole machines, which is a special feature. The rating is low, and all motors will stand an overload of 25 per cent. for one hour, or 50 per cent. momentarily. The motor is fitted to propeller fans as illustrated (Fig. 2), and also to those of the blower and exhauster type. These fans are claimed to be equal in efficiency to any at present before the public, and have gained a world-wide reputation. They are largely used by the H.M. Office of Works and the Post Office, and are ventilating numerous public buildings, such as the Houses of Parliament, Buckingham Palace, the Natural History Museum, various county courts, &c., &c.

The firm also make a speciality of induced draught for boilers, and pride themselves on the stability and finish of their fans for this purpose. They have lately carried out contracts in this line for the following corporations:—Leeds, Sunderland, Beckenham, and Govan; also for the Stalybridge, Hyde, Mossley, and Dukinfield Tramways, and numerous other public and private firms.

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Submarine Electric-bells.

The use of submerged bells as fog-signals at sea has not been adopted to any extent on our shores, although they are frequently used by other countries. At the request of the London and North-Western Railway Company, the Trinity House authorities are about to instal a system of electric submarine bell signals off the Lizard. These will be the first of their kind to be used in this country, and their operation will be followed with interest. It is doubtful whether any British electrical firm lists such specialities, but it would seem that now there is an actual demand it will be worth their while to give the matter full attention. In this connection we would refer readers to an article appearing in a recent number of the *Engineer*, in which several of the designs adopted abroad are described

One of these bells was put down as recently as September last in the outer entrance to Havre harbour. The entire mechanism, with the exception of the hammer and gong, are enclosed in a watertight cast-iron case and the complete bell either suspended—as from a lightship or in deep water from a lighthouse—or weighted to rest on the sea bed. The motive power used is a three-phase motor supplied by a ½h.p. oil-engine generating set. According to the writer of the article, M. Ribière, the chief engineer of the French Service des Phares, three-phase current is used for the following reasons:

(1) The timing of the signal is obtained by mechanical gears inside the bell and without interruption of the current, which remains constant, permitting the generator to run at constant speed; (2) during the intervals separating the signals there is an accumulation of energy in the mechanism; (3) the use of alternating current allows high tension to be employed with conductors of small section; and (4) the motors are simple and trustworthy, needing little attention, and can be run immersed in petroleum. It is said that the cost of the submarine electric bell at Cherbourg, with its electric generator and 500m. of cable, was about £240.

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A New Light Source.

It is well known that the aluminium electrodes of a condenser, rectifier, or lightning arrester cell emit small sparks over their surface when the voltage across the cell terminals reaches a certain value, the critical voltage depending upon the particular cell and the nature of the electrolyte. This phenomenon has been the subject of research, and highly interesting and valuable results have followed, as set forth by Mr. G. A. Johnstone in a recent number of the *Electrical World*. In the ordinary aluminium cell the sparks produced are spread over the surface of the electrodes, and are of short duration, gradually decreasing and finally dying away altogether as the voltage is maintained constant; a subsequent increase of the voltage restarts the sparking and a similar effect ensues. This curious property has been explained as due to the alternate breaking down and re-healing of weak spots in the film on the surface of the electrodes, and has been shown to be dependent upon the purity of the electrodes, inasmuch as with electrodes of pure aluminium the pressure required to set up the sparking is much higher than when crude, adulterated electrodes are used. The line of research followed, therefore, was the use of definite aluminium alloys. The results obtained in trying one combination in particular were so striking that they promised at once possibilities of usefulness. Moreover, an entirely new phenomenon was presented. The alloy was one that is used in making small aluminium castings, consisting of about 90 per cent. aluminium and the remainder mainly of copper and tin, with small quantities of manganese, iron, and zinc, and traces of silicon. With such a large percentage of foreign non-film-forming metals present, the alloy would hardly be expected to resist a very great voltage. It was found, however, that although the leakage was much greater than with pure aluminium, the pressure could be gradually raised to 250 volts without the passage of large currents. The electrolyte used most frequently was a solution of common borax, although other alkaline solutions gave similar results.

The light from this cell was found to be very different from that of one using pure aluminium. Instead of being described as sparking it can best be called glowing. With a cell that has been subjected to pressure for a sufficient time to form a considerable coating on the electrodes, the glowing is first noticeable at a pressure of from 40 to 50 volts in a room where the daylight is shaded, and increases in brightness with the e.m.f. until at 200 volts a stick electrode looks like a white-hot iron rod that has just been plunged into water. With a lower voltage the light is of an opal colour, presenting a glowing appearance of great evenness and brightness. When the e.m.f. is increased beyond 200 volts, small white, shifting sparks appear among the glow, which itself has become white.

The explanation of this effect which seems to best agree with the experiments is that the light emanates from a multitude of minute arcs that form at each point where the foreign substances appear. When viewed with a microscope the illumination does not separate into individual arcs, but this is, as would be expected, on account of the gas bubbles that are continually forming and shifting on the surface of the metal; moreover, the non-film-forming substances must be separated by molecular distances only. Further research with the proper equipment may determine that the gases present play an important part.

With alternating current the electrodes alternately glow and become dark in phase with the frequency. This fact was demonstrated when a cell having its two electrodes near each other was viewed with a stroboscopic disc. The light appears first at one and then at the other in the same way that the arc in a mercury rectifier is seen by means of a disc to leave one anode and appear at the other, only the light is less abrupt in changing from one source to the other in the aluminium cell.

The utility of the aluminium cell as a high-frequency indicating device is at once suggested, and already the principle has been applied to the design of a slip-meter with good results.

As to the intensity of the light, it is stated that a cell having two electrodes of about the size of a lead pencil, and consuming about 8 to 10 watts, emitted light sufficient to read small print held near the cell. Doubtless many others will be prompted to take up the study of this peculiar source of light, and adapt it to special technical and commercial requirements.

❧

The Coming of Aluminium.

JUDGING by the present state of the aluminium-making industry it would seem safe to predict that the year just started will see a remarkable increase in the use of aluminium in the electrical as well as in other industries. Open competition has already entered the field in Europe; many new works have recently started or are being put down in various countries. Notable amongst these is the new works of the Aluminium Corporation, Ltd., installed near Conway, North Wales, and replete with a hydro-electric power system and electric furnaces of the most modern description. Other works were started by the same company earlier in the year at Wallsend, and the British Aluminium Company, whose works at Foyers have been in operation since 1896, are now putting down a further plant of some 20,000kw. at Kinlochleven, which it is expected will start production early this year. The result of this development in manufacture on straightforward competitive lines has been the market supply of aluminium at £65 per ton, the price of which some two years ago was in the neighbourhood of £200 per ton. In the United States, the home of the industry, the holding of the Bradley patents vested the Aluminium Company of America with a monoply, and their products commanded a steady price of upwards of £180 per ton. Nowadays European aluminium is to be had in the States at a price of £140 per ton, and the home product has perforce been reduced accordingly. But even there the Bradley patents expire this year and prices will immediately be on the level prevailing on this side.

Whilst the present price here is about the same as that of copper, it would seem from figures of cost of production which are available that £65 per ton must be very near actual cost, and considerable fluctuations may be expected in the near future. However, it is certain that the prices of two years ago will never again be reached, and aluminium has definitely come as a powerful rival to copper for electrical usage.

* * *

A New Carbon Mercury Lamp.

A NEW lamp which is claimed to combine the advantages of the carbon filament and mercury-vapour lamps, being insensitive to shock like the former and having the economy of the latter, has been developed in Germany. The consumption of energy per candle-power is said to be about sixty per cent. less than that of ordinary carbon lamps. The lamp consists of a carbon filament fused into a U-shaped glass tube, which contains a drop of mercury and an indifferent gas in order to transmit the heat of the filament to the mercury. The U-shaped tube is then fused into a bulb, so that the completed lamp has the general appearance of an ordinary incandescent lamp. When the lamp is started the filament at first glows with a current consumption of about three watts per candle-power, like an ordinary lamp. As soon as sufficient mercury has been vaporised the light intensity increases more than twofold, so that the lamp consumes about 1.5 to 1.6 watts per candle-power. It requires about five minutes for the light to reach its full intensity, but as the lamp gives light from the moment current is turned on it may be used for all purposes. The lamps are made for all the usual tensions, and their life under normal conditions is from 600 to 1000 hours. The light is a pure white and contains no disagreeable green or blue rays.

* * *

Electricity on Shipboard.

DESPITE the fact that practically all modern passenger steamers and war vessels have some electrical plant aboard, even if it be only for lighting purposes, it is obvious to anyone who gives this subject much consideration that herein lies an immense field for the electrical manufacturer. There are a hundred-and-one uses to which the electric motor could be advantageously adapted on passenger and cargo steamers, and when one comes to warships the scope afforded is almost illimitable. Whilst it is a fact that our navy is about to be augmented by a large battleship in which electricity is to form the sole motive power for all auxiliary purposes, the proved reliability and convenience of the electric motor would seem to warrant its adoption in place of the existing compressed-air and hydraulic systems common in warships. Even where air compressors are indispensable, as for torpedo firing, the compressors are best driven by electric motor. Watertight doors have already been arranged for electrical operation in vessels of the United States Navy. A striking advantage of this arrangement is that the opening or closing of the doors can be readily indicated at a remote part of the ship. For such purposes as ammunition hoists and carriers, gun-laying, turret-moving, boat-raising and lowering, and ventilation, the electric motor has been frequently applied.

A remarkable feature of the adaptation of electricity in warship equipments is that for the "domestic" purposes. Many modern warships are fitted in a most thorough manner with electrically driven laundry machinery, and for baking and cooking they have such machines as dough-mixers, potato-peelers, meat-choppers, &c.

Comparing electricity with steam, pneumatic or hydraulic power aboard ship, the subject need not be gone into at any length to demonstrate that the electric motor will practically oust its competitors for all auxiliary purposes. In this connection it is somewhat strange that more attention has not been given to the use of polyphase currents aboard ship. The non-slip-ring, squirrel-cage motor affords the very highest degree of security, and particularly on warships its general use would appear to be imperative.

◆

A New Three-phase Locomotive.

FOUR three-phase locomotives have recently been constructed by the Ganz Company for the Valtellina railway which can be operated at three different speeds and possess some other novel features in the arrangement and construction of the motors. The locomotives are of the six-wheel type; their entire length between buffers is 11.54 metres; the diameter of the driving wheels is 1.5 metres, and of the trailing wheels, 0.8 metre. They have one eight-pole and one twelve-pole motor, each of them being operated by a current of 3000 volts and fifteen periods per second, supplied by overhead conductors. Three different speeds are obtained by using either one or the other motor separately, or both motors in series. With the eight-pole motor alone the normal speed is sixty-four kilometres; with the twelve-pole motor, forty-two kilometres, and with both motors in cascade 25.5 kilometres an hour. The motors are enclosed in a casing of sheet and forged iron, castings having been entirely avoided. The rotors are provided with three collector rings at the end opposite to the driving coupling, but the rings are on a separate shaft driven by a crank, in order to permit of easy access to all the parts of the machine. The brush-holders are fastened to the frame of the locomotive and enclosed in a sheet-iron box. The movement of the motors is transmitted to the driving axles by means of cranks, there being absolutely no gearing. The starting of the motors is accomplished by a liquid rheostat, consisting of a certain number of plates between which water is introduced by pneumatic pressure. The tractive effort at the lowest speed indicated is 6600 kilogrammes, and at the other two speeds 5500 kilogrammes. The 8-pole motor alone, in a one-hour test, developed 1100kw., the 12-pole motor 880kw., without the temperature rising above 75deg. C. The total weight of the locomotive is 62 tons; the adhesive weight, 42 tons.

◆

Trade Notices.

READERS are reminded that the 1909 Edition of the Electrical Trades Directory will be published at the end of this month, and that by ordering their copies before the 18th inst. they will save very considerably in the price. Every electrical man is familiar with "The Blue Book," which has for many years been looked upon as indispensable in business houses, and there is no need here to say anything further than that. The publishers promise additional useful features with their new issue, and an absolutely up-to-date reference directory of the electrical and allied industries.

Owing to the continued increase in their business, Messrs. Pritchetts & Gold, Ltd., have removed their Sales Department to larger premises at 59, Victoria Street, S.W., and all orders and correspondence with reference to that Department should now be sent to that address. The telegraphic address and telephone numbers remain unaltered.

The
Electrical Magazine.

VOL. XI. NO. 2. FEBRUARY 15th, 1909.

PROGRESS IN PHOTO-TELEGRAPHY.

VARIOUS attempts have been made to transmit photographs by electricity, some of them dating back to nearly a score of years ago, and although the results have been only of a more or less experimental nature up to last year, the method of Prof. A. Korn, of Munich, is now in commercial use at London, Paris, Berlin, Stockholm, and Copenhagen, and photographs are frequently telegraphed between these cities. Moreover, New York, Chicago, and other cities are now about to commence photo-telegraphic trials, and it therefore seems that an article dealing with the present state of photo-telegraphy will be opportune and of considerable interest and importance. Since November, 1907, the writer has carried out very numerous experiments between London and Paris at the installation of the *Daily Mirror*, from which much valuable information has been gathered, more especially as the submarine cable has caused many difficulties which provide useful experience for the future. An experiment was until recently carried out almost daily between the offices of the *Daily Mirror*, London, and *L'Illustration*, Paris, pictures being received by the former paper for publication purposes. The fire at the Paris Telephone Exchange put a temporary stop to these experiments.

The house of Scherl, in Berlin, has also a complete installation of Prof. Korn's apparatus, where, under the able management of Dr. Glatzel, much interesting work is carried out. Other methods of transmitting photographs by electricity are being experimented with by various persons, notably M. Belin* and M. Berjonneau,† whilst Charbonelle, Knudsen, and many others have also methods in an experimental stage which each hopes ultimately to develop.

At present the method of Prof. Korn is the only one which has stood the proof of practical commercial tests, and to him must be given the full credit and honour. The Korn transmitting instrument consists of a glass cylinder CC, on which is fixed a photographic film transparency, revolved by an axis A, which rises as it turns, so that different consecutive portions of the picture intercept at successive instants a beam of light which has its focus at F, a Nernst lamp, N_1, being used, run from accumulators. The light which penetrates the film is reflected by a 45° prism P on to a selenium cell Se, so that the latter is illuminated each instant in proportion to the opacity of the photograph. The resistance of the selenium is about 50 per cent. less when fully illuminated, and varies with the intensity of illumination, so that by sending an electric

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* See ELECTRICAL MAGAZINE, November, 1907.

† See ELECTRICAL MAGAZINE, January, 1908.

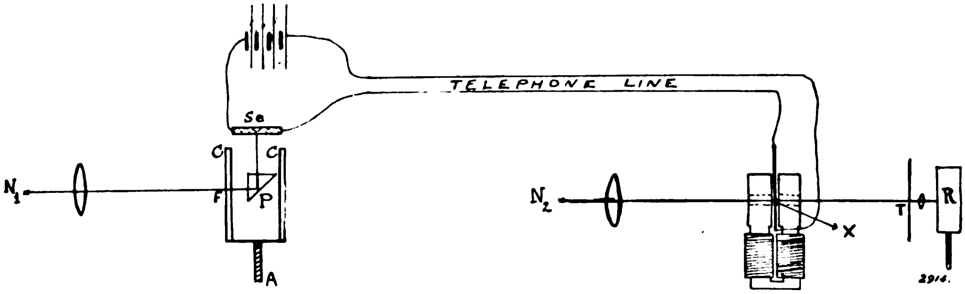

FIG. 1.

current through the cell to the receiving station the latter receives a current varying proportionately to the opacity of the photograph being transmitted. The received current is utilised to produce a lateral displacement of two fine silver wires placed in the field of a fairly powerful magnet, which is excited with 1amp. at 110 volts, and the magnet poles are bored with a circular tunnel through which a beam of light from the lamp N_2 is directed. In the path of the beam there is attached to the "strings" a small rectangular piece of magnesium foil X, a shadow of which is cast by a lens system on a diaphragm having a triangular aperture T; the light passing through this aperture is concentrated by a lens upon the receiving film R, so that a real image of the triangle falls on the sensitive film. This film, attached to a drum, is revolved synchronously with the cylinder of the transmitting machine, and as the shadow of the foil in the galvanometer shifts so as to allow the light to pass through the triangular aperture in a measure proportional to the opacity of that portion of the film being transmitted, the light falling on the receiving film as it rotates is such as to give a reproduction of the original.

Such is the theory of the transmission in the simplest and briefest form.

Certain complications are met with, however. In the first place, the change in the resistance of selenium does not follow the change in intensity of the illumination with sufficient rapidity. The change is not by any means dead-beat, a very considerable lag being experienced. This lag is overcome to a great extent by the ingenious compensation method which forms the basis of Prof. Korn's patent. In the sending machine, the galvanometer used for receiving is brought into requisition, being connected as a shunt on the line, and its movement thus corresponds with that obtained at the receiving station. But the light beam emergent from the field magnet boring is now reflected by a prism downwards upon a second selenium cell, the compensator. This has a high inertia and low resistance, the principal cell having a low inertia and high resistance (about 250,000Ω). Then, if e be the electromotive force of the battery, c the constant of the galvanometer, and w_1 and w_2 the resistances of the main selenium cell and compensating selenium cell respectively, the movement (a) of the magnesium foil in the galvanometer is approximately obtained from the equation:—

$$a = ce\left(\frac{1}{w_1} - \frac{1}{w_2}\right)$$

Since the displacement of the strings in the galvanometer is thus proportional within tolerably narrow limits to the difference between the reciprocals of the resistances of the two selenium cells, and thus to the difference between the current flowing through each, it is desirable that the effect of the illumination be as similar as possible in both the cells. Thus suppose in Fig. 2 that a and b are the two curves showing the relation between the increase of illumination and change in resistance: a will be that of the compensating cell, and b that of the principal cell, whose inertia is exceedingly small. After a certain increase

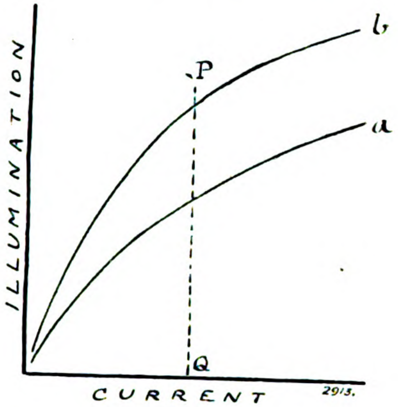

FIG. 2.

in the illumination from zero (where the axes of ordinates and abscissæ meet), the curves become nearly parallel with suitably chosen cells. Thus by making use of those parts of the curves to the right of the vertical line PQ, the quantity $\frac{1}{w_1} - \frac{1}{w_2}$ becomes fairly proportional to the increase in intensity of illumination.

Cells have to be chosen whose estimated curves are, beyond a certain limit, as nearly parallel as possible, whilst the conditions have to be chosen so that the parallel portions of the curves are made use of beyond this limit.

There is no doubt that much remains to be done regarding the construction of more sensitive cells, and the choice of better physical conditions for their employment. The lag which is observed in the return of the cell to its "dark" conditions, when the illumination is suddenly extinguished after its having been illuminated, might vary with different regions of the spectrum, &c. The relative sensitiveness of a cell experimented with by the author to light of different wave-lengths was :—

Band of spectrum used.		Current.	Current when not illuminated.
Blue Violet	380μ—470μ	0.21 milliampere	1.1
Green ..	470μ—580μ	0.22 ,,	1.1
Yellow ..	450μ—end of red	0.26 ,,	1.1
Orange ..	570μ—end of red	0.26 ,,	1.1
Red	610μ—end of red	0.25 ,,	1.1

The chemico-physical side of the question has unfortunately been somewhat neglected up to the present, and much work remains to be done in the direction of the manufacture of the cells. It is not at all likely that we have as yet got the most sensitive type of selenium cell producible. According to Ruhmer, it is possible to make cells particularly sensitive to rays of the longer wave-lengths by special means, and by producing a new and more sensitive type of cell and selecting the most suitable region of the spectrum for its illumination it is possible that further advance may be made. The writer has thus indicated some of the lines upon which future improvements may be worked out, but, although much research is now being carried out, it is too early to enter further into the matter.

In conclusion, it will be interesting to indicate, by means of actual photographs transmitted from Paris to London, some of the defects produced by the various phases

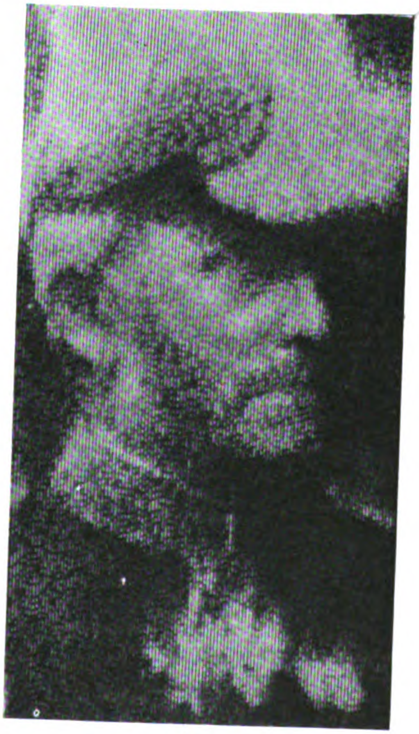

FIG. 3.

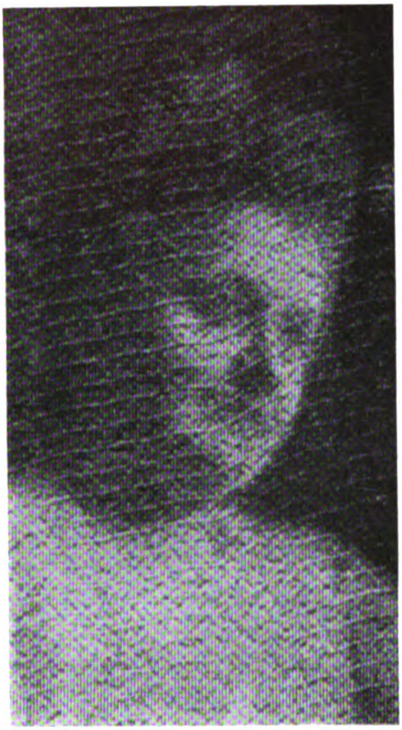

FIG. 4.

of the telephone lines. It should be said, in the first place, that as the maximum current transmitted to the receiving galvanometer is about 1 milliampere, the telephone lines connecting the two instruments must be completely isolated, and that the least leakage will be severely felt. The usual voltage through the line is 130 to 150.

As regards disturbances on the telephone line, that most frequently experienced appears to be due to the Baudot telegraphic system at work, when regular surgings can be heard on the line. A series of parallel bands, at regular intervals, of various shapes appears in the photographs, and these correspond with the number of noises heard in the telephone. An instance of such a picture is seen in Fig. 3, where the peculiar shape and character of the bands are seen. These bands, if very accentuated, entirely ruin the value of the photograph, and are, of course, caused by regular intermittent induced fluctuations of the current, which cause displacement of the silver wires in the galvanometer, with a corresponding movement of the shadow shutter.

Influences from the Morse telegraphic system can also be seen in the next illustration, which shows the effect of induction from a "Morse message." Considerable oscillation is found in the galvanometer on such occasions, and occasionally both Morse and Baudot markings are simultaneously produced. The oscillations from the former inductions are so violent sometimes that the wires are broken, and in consequence it is of little use attempting any transmission when such is the case. Curiously enough, also, the weather appears to have little influence in this direction, the condition of the "line" being perfect sometimes in an extremely wet time, and very bad in perfectly dry weather.

Leakage is, of course, a serious defect, as the current is so small. It is, however, possible to effect a transmission when the receiver only obtains 0.3 or 0.4 milliampere.

Capacity also affects the working of the machines, since in order to synchronise them it is necessary once in every revolution to switch out the "line" current from the galvanometer and to switch it into the relay which releases the receiving drum. The latter travels a little faster than the sending drum, and is stopped short when it has completed a revolution, the motor working temporarily against a friction clutch. A strong relay current is then sent to the receiver, which works the relay, and the latter, by a local battery, works a release, so that both the cylinders or drums commence their new revolution in unison.

In the various attempts now being made to transmit line drawings and photographs by a make-and-break contact the telephone line will be dispensed with, and a telegraph line and earth return be used. Here special arrangements are made to overcome any capacity effect, and these will be described in connection with the general apparatus, in a future article.

T. THORNE BAKER.

A SERIES OF COMPARISONS BETWEEN ELECTRICITY AND GAS.

2.—In Domestic Heating and Cooking Service.

In 1897 Jackson of Pennsylvania came to the conclusion, from a series of tests, that electricity for use in cooking was five times as dear as coal gas. It is the object of this article to show that the ratio of the cost of electricity to the cost of gas for cooking and heating is now very low, and though still greater than unity in some cases, yet taking into account all the increased efficiency, cleanliness, and convenience offered by electricity the latter is superior to gas in all phases of domestic service. Since coal and oil play such important parts in domestic heating it is proposed to rather strain the original scope of this series of articles by including some comparisons between coal, coke, gas, oil, and electricity. Though electricity may, at first sight, appear to be very dear, the writer believes that it will be acknowledged that the apparatus for its utilisation has now been brought to such perfection that *on the whole* electrical energy is superior to other heat agencies. As is shown later, it only rests with the manufacturers of electric stoves, &c., to vastly extend the use of such apparatus by turning out a cheaper and more substantially built line of goods.

In the present article the subject of domestic heating and cooking is alone dealt with, the problems of industrial heating being much more complex and being governed by such diverse factors as to require quite separate treatment.

In the first place some relations must be obtained between the values for heating purposes of 1lb. of coal or coke, 1c.ft. of coal gas, 1lb. steam (under given conditions as to temperature and pressure), 1lb. water (at a stated temperature), 1 pint of oil and 1 b.o.t. unit of electricity. In Table I. such relationships are expressed and enable data relating to one form of energy to be readily converted into the corresponding data relating to any other form of energy. It will be seen that in this table theoretical equivalents are first given (*i.e.*, the equivalents assuming 100 per cent. efficiency of conversion from one form to any other), and appended are a set of equivalents assuming such efficiencies for the various processes of conversion of different forms of energy to available heat as are likely to occur in domestic practice. The applications of each set of figures will be obvious.

The data appended to Table I. (in footnote) regarding the possible performances of central stations is of use when considering such a case as: "Instead of burning x lb. of coal in our grate we may use y b.o.t. units of electrical energy, which require z lb. of coal for their generation at the central station." The data given includes gas plant to a certain extent, but the performance of the latter depends so vastly on the exact gas analysis and on the size of units installed that typical data are of little value. As relating to coal and the volume of coal gas obtainable from it, it may be noted that in the case of Manchester the mean cubic feet gas per lb. of coal distilled is 4.9c.ft., this being quite a representative result.

Taking coal, coke, gas, &c., at the rates

TABLE 1.—TABLES SHOWING THEORETICAL AND PRACTICAL EQUIVALENTS OF VARIOUS FUELS AND FORMS OF ENERGY (OF USE WHEN ESTIMATING COAL AND GAS EQUIVALENT OF 1B.T.U. &c.)

				Equivalent to								
		Value in British Thermal Units.	Per Cent. Efficiency	Electricity B.T.U.		1lb. Steam †	1lb. Water. ‡	1lb. Coal.	1lb. Charcoal.	1c.ft. Coal Gas.		1lb. Oil.
THEORETICAL.	1B.T.U. Electricity ..	3410	100 %, *i.e.*, taking theoretical equivalents.	1.00		0.34	0.029	4.09	4.25	0.19		5.71
	1lb. Steam†	1161		2.94		1.00	0.087	12.00	12.55	0.56		16.80
	1lb. Water‡	100		34.10		11.60	1.00	139.0	145.0	6.50		195.0
	1lb. Coal	14,000		0.245		0.084	0.0072	1.00	1.04	0.047		1.40
	1lb. Charcoal	14,500		0.235		0.080	0.0069	0.96	1.00	0.045		1.34
	1c.ft. Coal Gas	650		5.25		1.79	0.154	21.50	22.4	1.00		30.00
	1lb. Oil ‖	19,500		0.175		0.060	0.0051	0.74	0.745	0.033		1.00
* PRACTICAL.	1B.T.U. Electricity—Radiator	3240	§95%	1.00		0.144	0.0185	0.861	1.56	.060	.170	5.10
	Convector	3340	98%	1.00		0.139	0.0180	0.840	1.52	.058	.164	4.95
	1lb. Steam†	465	40	6.98	7.20	1.00	0.129	6.00	10.9	0.42	1.18	35.60
	1lb. Water‡	60	60	54.0	55.8	7.76	1.00	46.5	84.5	3.25	9.15	275.0
	1lb. Coal	2800	¶20	1.16	1.19	0.167	0.022	1.00	1.82	0.07	.197	5.91
	1lb. Charcoal	5080	35	0.64	0.66	0.092	0.0118	0.551	1.00	.039	.108	3.27
	1c.ft. Coal Gas with flue	195	30	16.6	17.2	2.38	0.308	14.30	26.0	1.00		84.8
	,, ,, without flue	550	85	5.9	6.1	0.848	0.112	5.10	9.20	1.00		30.1
	1lb. Oil	16,550	85	0.196	0.202	0.028	0.0036	0.169	0.30	.012	.033	1.00
		B. Th. U. available as desired.										

* The efficiencies assumed in this section are suitable for domestic apparatus, grates, &c. For other applications other efficiences would be necessary, as shown later. Thus, considering central station efficiencies, with the following plant the results shown obtain :—

Suction Gas Plant 1¼lb. coal per B.T.U. (Guaranteed).
,, ,, ,, (by another maker) 2.8lb. coal per B.T.U. (Guaranteed).
Berlin generating station (steam) 2.38lb. coal per B.T.U. (average for one year).

† Taken dry and saturated at 260deg. F. (*i.e.*, at 20lb. per square inch pressure).

‡ Taken at 150deg. F. and the sensible heat reckoned from 50deg. F.

‖ Sp. gr. about 0.825.

§ These efficiencies refer to electric heaters, steam and water boilers (domestic), coal grates and charcoal, gas, and oil stoves respectively.

¶ This efficiency is higher than obtainable in most grates.

indicated, the cost of available heat per 1000 British Thermal Units is as in Table II., the two sections again corresponding to 100 per cent. efficiency of conversion and average domestic efficiencies respectively. These figures, even assuming it possible to consider correct typical efficiencies, must not be accepted as yielding any final conclusion, since the relative costs of installation and value of convenience and cleanliness must be allowed for.

Water and steam heating are included in the subsequent comparison, though the volume of space to be heated is usually insufficient to warrant the very high initial cost of these systems. This being so, their greatest application is in industrial heating as later.

TABLE II. (BASED ON TABLE I.).—COST OF HEAT PER 1000B.T.U. BY VARIOUS METHODS.

	Form of Energy.	Rate per Unit of Energy.	Pence Cost per 1000 Brit. Therm. Units.	Relative Costs with Electricity at 1d. per unit as Standard.
Assuming 100 per cent. efficiency of conversion.	Electrical.	0.75d. per b.t.u.	0.220	0.75
		1.00d. ,, ,,	0.293	1.00
		1.50d. ,, ,,	0.440	1.50
	Steam Heating (coal-fired)	10/- per ton.	0.046	0.157
		17.5/- ,, ,,	0.081	0.276
		25/- ,, ,,	0.116	0.395
	Water Heating (coal-fired)	10/- ,, ,,	0.540	1.840
		17.5/- ,, ,,	0.940	3.200
		25/- ,, ,,	1.240	4.240
	Coal.	10/- ,, ,,	0.00384	0.0131
		17.5/- ,, ,,	0.0067	0.0228
		25/- ,, ,,	0.0096	0.0327
	Charcoal.	16/- per cwt.	0.118	0.402
	Coal Gas.	2/- per 1000c.ft.	0.037	0.126
		3/- ,, ,, ,,	0.055	0.188
		4/- ,, ,, ,,	0.074	0.252
	Oil *	70/- per ton.	0.0193	0.0658
		100/- ,, ,,	0.0275	0.094
Assuming suitable domestic efficiencies of conversion.	Electrical (96.5 per cent. mean efficiency). †	0.75d. per b.o.t.u.	0.227	0 750
		1.00d. ,, ,,	0.303	1.000
		1.50d. ,, ,,	0.445	1.500
	Steam Heating (coal-fired).	10/- per ton.	0.116	0.383
		17/6 ,, ,,	0.202	0.668
		25/- ,, ,,	0.289	0.952
	Water Heating (coal-fired).	10/- ,, ,,	0.897	2.950
		17/6 ,, ,,	1.565	5.180
		25/- ,, ,,	2.240	7.390
	Coal.	10/- ,, ,,	0.0192	0.0632
		17/6 ,, ,,	0.0335	0.1105
		25/- ,, ,,	0.0480	0.1580
	Charcoal.	16/- per cwt.	0.337	1.115
	Coal Gas (57.5 per cent. mean efficiency). †	2/- per 1000c.ft.	0.0642	0.213
		3/- ,, ,,	0.096	0.317
		4/- ,, ,,	0.1285	0.425
	Oil*	70/- per ton	0.0227	0.075
		100/- ,, ,,	0.0324	0.1065

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* In this row good quality commercial fuel oil (*e.g.* "Astatki") is referred to. The carriage and handling of large quantities of oil is difficult, dangerous, and costly.

See Table I., showing actual efficiencies under various conditions.

TABLE III.—EFFICIENC

TYPE OF HEATER.	CONSUMPTION PER HOUR at capacities of (in thousands of c.ft.).								VOLUME OCCUPIED BY HEATER (C.F at capacities of (in thousands of c.				
	0.5	1.0	2.0	3.0	4.0	5.0	10.0		0.5	1.0	2.0	3.0	4.
Electric Radiator..	0.5	1.0	2.0	2.75	3.5	4.25	7.5	B.T.U.	0.63	0.89	1.66	Use con	
Electric Convector	0.5	1.0	1.75	2.15	2.85	3.5	5.5	B.T.U.	—	0.90	2.39	3.3	3.8
Steam (Coal-fired)	Not applicable						10	℔	Boiler data		—	—	—
									Radiator data		3.0	4.25	5.2
Steam (Gas-fired)..	—	8	14	16	24	26	50	c.ft.	—	1.7	2.09	2.5	2.9
Hot Water (Coal-fired)*	Boiler data			2.5	3.0	3.4	5.0	℔	—	5.0	5.03	16	22
	Radiator data			—	—	—	—	—	1.0	1.2	2.6	4.0	6.4
Coal	2.0	3.0	4.0	9	9	15	20	℔	6.6	8.2	10.5	Use sever	
				Using 2 or more grates									
Charcoal	—	.125	.25	.375	.438	.50	—	℔	—	0.59	1.76	2.4	3.4
Gas (with flues)†	14	17	26	30	35	42	75	c.ft.	—	1.4	3.0	4.6	5.7
Gas (without flues)	16	20	30	35	41	49	88	c.ft.	—	3.3	5.0	6.6	7.9
Oil Stoves	0.6	0.76	1.0	1.3	1.6	1.9	3.5	pts.	0.7	1.3	2.6	3.4	4.0
Central Coal Stoves	Not advisable			1.0	1.25	1.5	2.0	℔	—	0.9	1.0	1.1	1.15
Gas Radiator ‡	Rather higher than ordinary gas stoves								—	—	—	—	—

* Not suitable if less than 7000c.ft. is to be heated. In the case of hot water and steam heating the volume data do not include the space occupied by the piping. † Gas at 2in. water pressure.

‡ These comprising gas stoves in which air is sucked over heated metal ribs.

‖ In the case of coal grates it is very difficult to attach any exact volume to the whole.

§ These weights are only approximate : the weight of the lamps is negligible, only that of the framework being appreciable.

It will be seen that electric heating, being the result of the double transference of heat to electrical energy at the central station and electrical to heat energy in the consumers' rooms, can only be cheaper than direct heating of the latter by coal if the efficiency of the double conversion is higher than that of the single conversion in the domestic grate. Now the efficiency with which coal is burnt in a modern boiler is far greater than the efficiency with which it could be burnt in any domestic grate, and the excess efficiency may well more than compensate for the losses in generation, transmission, and reconversion of electrical energy in domestic units. This will be more especially so in gas-driven stations where the performance of that most inefficient link in the otherwise usually existing chain—the steam engine—is greatly improved.

Thus it is now quite within the range of possibility that electrical energy will actually be cheaper than coal for domestic uses even in fuel cost alone, owing to the greater efficiency of the *central burning of fuel.* It will be apparent later that in many industrial processes similar conditions arise, coal can be burnt in central boiler furnaces, and thence electrical energy obtained, which may be utilised much more efficiently at the point required (whether by heating resistances or by an arc) than any coal, gas or oil furnace, as to more than compensate for all losses in the double conversion of energy now necessary.

It is clearly logical that steam and hot water heating should be included in these comparisons, since there again we may have *central* coal burning; and, moreover, we now avoid the losses in the steam engine, generator transmission lines, and electric

F DESIGN DATA. ROOM HEATERS.

		WEIGHT, LB. ¶ at capacities of (in thousands of c.ft.).							Volume (c.ft.) per 1000c.ft. heating capacity at capacities of			Weight (lb.) per 1000c.ft. capacity at capacities of			Installation cost (pence) per 1000c.ft. capacity at capacities of		
	10.0	0.5	1.0	2.0	3.0	4.0	5.0	10.0	1000 c.ft.	2000 c.ft.	5000 c.ft.	1000 c.ft.	2000 c.ft.	5000 c.ft.	1000 c.ft.	2000 c.ft.	5000 c.ft.
ors		10§	20	30	Use convectors				0.89	0.83	—	20	15	—	540	—	—
	5.5	15§	25	30	33	35	40	Use several	0.90	1.19	0.88	25	15	8	540	435	336
	6.25	—	—	—	—	—	600	800	0.625	at 10,000c.ft.		at 5,000c.ft. 120lb. at 10,000c.ft. 80lb.			—	—	Total
	9.5	—	170	340	540	720	900	1550	—	1.5	1.25	170	170	180	—	—	456
	6.1	—	120	300	500	590	660	1000	1.7	1.05	0.68	120	150	132	720	515	312
	30	—	200	370	500	600	670	1000	5.0	2.52	5.0	200	185	134	—	**	Total
	19	150	240	560	750	1000	1200	2200	1.2	1.3	1.8	240	280	240	—	**	624
grates‖		40	60	180	Use several grates				8.2	5.25	—	60	90	—	600	480	—
	11.4	—	35	65	94	118	135	200	0.59	0.88	0.94	35	32.5	27	300	270	264
	11.4	—	25 to 30	55	80	108	130	200	0.4	1.5	1.38	25 to 30	27.5	26	408	300	209
	14.0	—	50	85	112	140	160	240	3.26	1.98	1.84	50	42.5	32	720	570	408
	6.2	40	55	80	104	128	148	250	1.3	1.3	0.9	55	40	74	420	360	312
	2.1	—	140	150	164	175	180	300	0.9	0.5	0.25	140	75	90	480	240	228
	—	—	—	—	—	—	—	—	Approx. 2c.ft.			—	—	—	About 20/- per 1000c.ft. warmed		

¶ Grates assumed empty in the case of coal stoves: water radiators, &c., assumed full.

** At 10,000c.ft. capacity the total cost per 1000c.ft. capacity=486d.

N.B. In the three last main columns of the table any discontinuities, &c., are due to the inherent differences of design of heating units of different capacities. Owing to this difficulty and to the many makes of apparatus on the market, the above table must be considered as giving the order and average value of the various magnitudes.

heaters, which are inevitable when using the latter. One would expect, therefore, that steam heating would be much cheaper than electric or coal heating, and though this is so as regards fuel costs (see Table II.), yet the heavy labour of attendance and depreciation costs greatly increase the gross cost per 1000 hours of heating, and leave the gross steam cost some 50 per cent. higher than the gross electrical cost, while the former method is much less convenient than the latter. Owing to these heavy labour and depreciation charges it is the independent gas-heated steam radiator that shows up best on the whole, for though its fuel charge is heavier, the cost of labour and depreciation are much less.

Before entering on the detailed systematic comparison of the sources mentioned, it will be well to state clearly the three methods by which heat may be transferred from one body to another. This is a purely physical point, but one which bears very largely on the relative suitability of various heaters for various situations.

Heat may be transferred from a body A at any temperature to a body B at a lower temperature by (1) *conduction*, (2) *convection*, (3) *radiation*.

In *conduction*, bodies A, B are either in mechanical contact themselves or are connected by a heat conducting medium—they must be thermally connected. In this case a layer of particles next to A is heated by contact with A, and this layer then heats the next and so on, the heat transference consisting of a transference from particle to particle right through the connecting material. To enable this, there must be a temperature gradient (*i.e.*, a fall of temperature from A to B, which follows a steady law of decrease, as shown by Inginhaus' experiments). The rate of heat transference by conduction depends on the steepness of the above thermal gradient and on the conductivity of the thermal connecting medium. In the present series of considerations we meet with conductivity when considering the transference of heat from the furnace to the water in a boiler, and thence through the metal of the distributing pipes to the outer layer of metal from which it is dissipated by convection and radiation.

Convection consists in the transference of heat from the body at the higher temperature by the heating of the particles of a liquid or gas in contact with it by *conduction* in the first place. In consequence of their raised temperature the density of these particles decreases, and they therefore rise, being replaced by denser, cooler particles, which in turn abstract heat by conduction, and rising, give place to yet another set of cool particles, and so on. This process of heat abstraction by a rising stream of particles is termed *convection*, and is met with in practice in the heating of rooms by stacks of steam pipes or by electric convectors, the rising particles here being of air, while in water boilers, &c., the rising particles are of water.

Radiation.—In this method of heating, heat is emitted—*radiated*—from the hot body in every direction, and heats those bodies on which it falls without appreciably heating the intervening medium at all. It is by radiation that we receive the warmth of the sun; the intermediate 90×10^6 miles of space is not appreciably warmed by the passage of the heat waves, but directly these waves encounter solid material, such as our bodies, the earth, &c., the temperature of the material is raised.

The object of the above apparent digression will be obvious when it is remembered that kettles, &c., are heated by conduction and convection; ovens, and in some cases rooms, by convection; while other types of ovens and methods of room heating utilise radiation. The particular applications of these various systems is dealt with later.

Even in such a small branch of the science of electrical engineering as that of domestic heating there are so many different applications and principles to be regarded that a scheme of subdivision is essential before further progress can be made.

The three main headings under which domestic heating may be classified are :—

1. Room heating, including the special cases of cupboard or hot chamber heating.
2. Cooking and food heating.
3. Water heating, this presenting different features to (2), since the temperature range is definitely fixed and the weight of material to be heated is usually greater than in cooking operations. Moreover the water is contained in a vessel so that it is in direct thermal contact with the heating elements, whereas in ovens hot air is the actual heating agent affecting the articles to be cooked.

Treating the above main sections in turn we may deal in each with the following points for coal, coke, steam, gas, oil, and electrical energy :—

(*a*) *Inducements* offered to the use of each source of energy—as offered by the vendors of each.

(*b*) *Essentials of the apparatus* used in each application—merely stated now; how each fulfils these requirements will be apparent as the comparison proceeds, results being summarised at the end of the article.

(*c*) *Cost of installing* apparatus and accessories for the consumption of each form of energy.

(*d*) *Cost of building*, including chimneys, coal, store-houses, &c.

(*e*) *Cost of use* of each form of energy, including the cost of various fuels, the cost of repairs and renewals, the life of various parts of the equipment, and the actual efficiencies obtainable as well as the conditions leading to higher efficiency.

(*f*) *General points*, including the following :—Temperatures attainable with each form of heating, effect of the temperature required on efficiency, the temperature most desirable, and so on. Also the weight and volume per unit effect, expressed in British thermal units and per 1000c.ft. heating capacity, are treated, these coefficients being excessive in some types of heaters.

(*g*) *Placing of various types of heaters.* Points to be noted in various applications, length and design of inlet and outlet ducts, &c.

(*h*) *General advantages* of each system and particular conveniences and risks. Points affecting the decision to install a certain system in any particular instance. Comparison of appearances.

(*i*) *Distinctive applications* of each—as influenced by the nature of the work to be done, locality, nature of surroundings, and exact requirements to be fulfilled.

(*j*) *Health conditions* and *indirect costs.* These sections are in many instances the same as those adopted in the articles on lighting already published, and this is evidently logical since the difference between heat and light emanations is merely one of *degree*—a difference merely of temperature of the source.

Sub-section (*a*) may be treated for all the main sections 1, 2, and 3 simultaneously, but in sub-sections (*b*) to (*j*) it will be clearest to take each division in its relation to room heating, cooking, and water heating in turn, finally collecting such points as are of general application in the concluding summary. Having set out the lines along which the comparisons are proposed we may proceed to treat each item in turn :—

Inducements. — These inducements are practically restricted to the use of electricity, and, being much the same as those indicated fully in the lighting articles, need only be briefly stated. As before, we will neglect such spurious inducements as free stoves, &c., since the consumer has ultimately to pay for them in one form or another. At the same time it must not be ignored that the possibilities now offered of hiring electric stoves on the same terms as gas stoves are doing much towards extending the use of the former. The great inducement to the use of electrical energy, however, lies in much reduced rates charged, when this energy is required for heating or cooking purposes. As shown by Tables I. and II., this cheap rate coupled with the high efficiency of electrical apparatus brings the cost of use per 1000 British thermal units available down to a figure favourably comparable with the cost of gas and coal. (See also Tables XIII. and XIV.)

Whereas the charge for "lighting" energy averages 3d. per unit (this average being that of a very large number of districts), the heating rate is ¾d. to 1d. per unit in the majority of cases, seldom exceeding the latter figure, while there is every reason to anticipate that ¾d. will soon be the general rate. In many instances the heating rates are cut so low as to equal, if not be less than, the cost of their production, the reason for this apparent generosity on the part of the central station lying in the anxiety of the engineers to improve their load factor by the introduction of constant loads. Though this at present is a further inducement to the use of electrical energy, the policy cannot be regarded as a stable one, nor as one to be commended from the point of view of sound finance.

As in the case of lighting, a consumer can obtain further reduced rates if he can contrive to confine his heating to certain "slack" hours of the station.

No such facilities for cheapening the supply are offered by gas authorities, and, of course, in the case of steam heating this section has no significance. With oil, coal, and coke the only means of cheapening their use that could be termed an inducement, lie in the wholesale purchase of these fuels. Now the retail prices and the reduction allowed for wholesale quantities vary widely with the district, but since, where coal is cheap, electrical energy can also be generated cheaply, it will be fair to assume average prices for both coal and electricity, this average being taken for a number of towns neither directly in the coal areas nor remotely removed from them.

Much of the economy resulting from the wholesale purchase of coal and coke is offset

TABLE IV.—COST OF INSTALLATION—

TYPE OF HEATER.	BUILDING.‡			GENERATOR OR BOILERS, &c.*										
	Saving by Electricity on			Heating Capacity 1000's cubic feet.										
	Chimneys	Hot Chambers &c.	Fuel Houses, stores, &c.	5	7	9	10	15†	20†	60†	70†	150†	0.25	0.50
				£	£	£	£	£	£	£	£	£	£ s. d.	£ s. d.
Electric Radiator	—	—	—	—	—	—	—	—	—	—	—	—	0 18 0 —	1 10 0 2 10 0
Electric Convector	—	—	—	—	—	—	—	—	—	—	—	—	1 0 0 —	1 10 6 —
Steam (coal-fired)	See letterpress : similar to coal			—	—	10	12	17	22	52	58	88	— —	— —
Independent Gas-steam units	—	—	—	—	—	—	—	—	—	—	—	—	— —	2 0 0 —
Hot Water (coal-fired)	See letterpress : similar to coal			5	7	8	10	13	16	40	45	75	— —	— —
Coal	£30 to £40‖	—	£5 to £10 §	—	—	—	—	—	—	—	—	—	— —	— —
Charcoal	—	—	—	—	—	—	—	—	—	—	—	—	— —	— —
Gas (with flues)	—	—	—	—	—	—	—	—	—	—	—	—	— —	— —
Gas (without flues)..	—	—	—	—	—	—	—	—	—	—	—	—	— —	— —
Oil	—	—	—	—	—	—	—	—	—	—	—	—	— —	1 0 0 D*2 0 0
Central Slow-combustion Coal Stove	Similar to coal	£8 15 0	Similar to coal	—	—	—	—	—	—	—	—	—		

* No piping is included in these estimates. § Rising to £30 to £50 in large establishments.

† These sizes really come under the Industrial section and are dealt with more fully there.

‡ These costs are estimated for a villa costing about £1000 to erect.

‖ Allowing for overmantles, &c., this would amount to £60 to £70.

by the cost and inconvenience of storing large quantities, while this objection is even more applicable in the case of oils, a fireproof underground storage pit having to be provided for their storage as a rule if insurance of surrounding property from fire is desired.

Essential requirements of heating agencies for services (1), (2), (3).

Though these requirements are termed "essential," "ideal" would perhaps be a better term, since few heating equipments can lay claim to the fulfilment of more than a few of them. Electricity, however, affords the closest approximation to their complete satisfaction. In all three sections the source should be as cheap as possible, both in prime and operating costs, the latter including repairs. The amount of accessory apparatus should be as small as possible. The source should be "clean," making a minimum of dirt during operation and producing no fumes or noxious gases. The source of heat should be capable of easy and exact temperature regulation over a wide range, and, once adjusted, should remain constant in its effects till intentionally varied. The heating effected should be equable and not locally intense, except in certain special requirements referred to later. During operation the attention required for stoking, &c., should be a minimum.

In general the space occupied by the

ROOM HEATERS.

Radiators, Convectors, Stoves, &c.									**	Remarks
Heating Capacity in Thousands of Cubic Feet.										
0.75	1.00	1.5	2	3	4	5	7	10		
£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.		
2 0 0	2 5 0	3 10 0 to 5 10 0	—	—	—	—	—	—	Plain	Above 1500c.ft. preferably use convectors.
3 0 0	2 10 0	9 10 0	—	—	—	—	—	—	Decorative	
2 0 0	2 5 0	2 19 0	3 12 6	4 15 0	6 0 0	7 0 0	—	—	Plain	Above 4000c.ft. use a distributed number of smaller units.
—	¶	¶	—	—	D*10 0 0	—	—	—	Dec.	
0 15 0	1 0 0	1 17 0	1 12 0	2 5 0	2 16 0	3 15 0	5 5 0	7 0 0	Plain	—
—	2 0 0	—	D*5 0 0	—	—	—	—	D*£20	Dec.	
—	3 0 0	3 15 0	4 6 0	5 4 0	6 0 0	6 10 0	7 16 0	9 10 0	Plain	—
—	—	—	—	—	—	—	—	—	Dec.	
1 8 9	2 0 0	2 15 0	3 17 0	5 10 0	7 17 0	8 12 0	9 10 0	--	Plain	—
—	—	—	6 0 0	—	—	—	15 0 0	--	Dec.	
2 0 0	2 10 0	3 0 0	4 0 0	Use several smaller units					Plain	Heating capacity of grates is very indeterminate.
3 0 0	4 0 0	5 0 0	6 0 0 DD						Dec.	
—	1 5 0	—	2 5 0	3 10 0	—	5 10 0	—	—	Plain	Extremely unhealthy
—	—	—	—	D*11 0 0	—	—	—	--	Dec.	
1 3 0	—	2 5 0	—	2 15 0	3 10 0	4 7 0	5 15 0	7 10 0	Plain	—
—	—	D*5 0 0	—	DD3 15 0	—	—	—	—	Dec.	
—	3 0 0	4 0 0	4 15 0	6 5 0	7 10 0	8 10 0	10 10 0	13 0 0	Plain	Very unhealthy
—	—	—	—	—	—	—	—	—	Dec.	
—	1 15 0	2 5 0	3 0 0	4 0 0	5 10 0	6 10 0	9 0 0	12 0 0	Plain	—
—	D*2 10 0	—	D*4 10 0	—	—	—	—	18 0 0	Dec.	
Not advisable				2 0 0	—	4 15 0	—	5 0 0	Plain	—
				7 0 0	—	7 0 0	—	9 0 0	Dec.	

¶ These sizes are obtainable in the enamel-embedded class for £2 10s. to £4.

** A standard degree of decoration has been kept to as closely as possible, the grades being D, DD, D*. See also letterpress.

heating apparatus should be as small as possible, and the weight of the units should be a minimum : the source and its accessories should offer a minimum of obstruction and inconvenience to other operations, and *should be portable.*

In cooking operations the heating should be confined to the required spot and not diffused into the entire room, whereas the converse is the desideratum in room heating. In the latter operation, wastage via the chimney or via outgoing air currents, must be carefully avoided. Waste gases, if unavoidable, must escape at as low a temperature as possible, yet must be removed ere they unduly vitiate the atmosphere. This is particularly so in gas ovens : the system which permits food stuffs to soak in a mixture of carbon dioxide and sulphur dioxide for several hours immediately prior to their consumption is obviously extremely bad from a hygienic point of view.

The extent to which each system of heating conforms to the above requirements will be apparent in the later stages of this article. The various costs, prime and running, are compared in Tables IV.-VI. and VIII.-XIII., while the amount of accessory apparatus is set out in Table VII. It is obvious that electric heaters are superior to all others in the matter of cleanliness of operation, this feature being more fully dealt with in the "Health" section. Particulars of the

TABLE V.—COST OF INSTALLATION—COOKING

Means of Heating.	Ovens.																	
	c. ft. Available Space.												Consumption at Capacities.					
	.25		1.0		1.5		2		4		5		.25	1.0	1.5	2.0	4.0	5.0
	A*	B*	A	B	A	B	A	B	A	B	A	B	—	—	—	—	—	—
			£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.						
Electric	—	—	5 15 0	1 15 0	‖6 2 6	2 10 0	6 10 0	3 0 0	7 15 0	7 0 0	9 0 0	7 0 0	—	500, 1000 & 1250 watts.	500, 1000 & 1500 watts.	§	§	1000, 2000, & 3000 watts.
Particulars of B*	—	—	1 Boiler 1 Griller		2 Boilers 1 Griller		2 Boilers 1 Griller		5 Boilers 2 Grillers		5 Boilers 2 Grillers		—			—	—	
Gas Stoves ..	—	—	£2 10 0		£3 5 0		£3 15 0		£7 15 0		£8 10 0		—	10c.ft. per hr.	13c.ft. per hr.	17.5c.ft. per hr.	33c.ft. per hr.	40c.ft. per hr.
Coal	—	—	¶£2 0 0		£4 0 0		£5 10 0		£8 10 0		£9 5 0		—	3.5lb.	4.4lb.	5.0lb.	9.0lb.	12lb.
Oil	18/-		£2 0 0		£2 18 0		£5 5 0		£9 0 0		£10 10 0		Pint 2/3.	Pint 0.8	Pint 1	Pints 1.2	Pints 2.3	Pints 3

* A=cost of electric stove alone. B=cost of disc stoves, grillers, &c., as specified on line below in each case to bring electrical equipment up to same capacity as that of the gas stoves.

‖ 100 v. winding (10/- extra for 200 v. winding).

§ The heaters in these stoves would be about the same as in the 1.5c.ft. oven and 5.0c.ft. sizes respectively, the full heat being kept on longer in the first instance and shorter in the second.

TABLE VI.—COST AND PERFORMANCE OF

Urns.					
Type of Heating.	Capacity.				
	1 gall.	2 gall.	3 gall.	5 gall.	Finish.
Electric—					
Cost	£2 10 0	£3 15 0	£4 8 0	£6 0 0	Tin.
	£5 0 0	7 0 0	8 10 0	7 0 0	Copper.
Watts	250 and 1000	300 and 1500	350 and 1200	500, 1000, and 2000	
Time to boil	25 mins.	40 mins.	74 mins.	74 mins.	†
Cost of similar urn for gas or oil	£0 12 0	£0 16 0	£1 0 0	£1 8 0	Tin.
	1 7 0	1 15 0	2 2 0	3 0 0	Copper.
Gas ring for ditto ..	0 2 6	0 3 6	0 4 6	0 6 0	

Tank Boilers.*				
Type of Heating.		Rate of Boiling per min. from 60deg. F.	Cost of Installation	Consumption. Watts, &c.
Electric, 1 gall. size..		0.0373 gall. per min.	1 0 0 3 7 6	1100 watts.
	1.5 ,,	0.044 gall. per min.	3 12 6	325, 650, & 1300
Oil,	3.0 ,,	0.120 gall. per min.	3 3 0	1½ pint per hour.
	6.0 ,,	0.134 gall. per min.	6 6 0	3 pints per hour.
Gas,	5 ,,	0.083 gall. per min.	3 10 0	30 (?) c.ft. per hour.
	8 ,,		2 10 0	80c.ft. per hour.
	12 ,,		2 15 0	80c.ft. per hour.

* Coal boilers are omitted from this section since separate coal boilers are not suitable for ordinary domestic supply and the boilers in coal ranges are remarkably inefficient (see however Table XIV.).

† The shortening of these times is at once effected by increasing the wattage of the *full heat* elements; the "maintaining" elements should be left unchanged.

SECTION.†—OVENS, KETTLES, SAUCEPANS.

	KETTLES.						SAUCEPANS.					
	Capacity (pints).						Capacity.					
	1.0	1.5	2.0	3.0	4.0	6.0	1.5 Pints	2 Pints	4 Qts.		6 Qts.	
Electric : Wattage	360	500	500 800	800	250, 500, & 1000	1300	400	250	400	1000/320	450	1000/350
,, Cost.	£2	£1	10/- 18/-	£1 12 6	£1 15 0	£1 17 6	16/6	25/-	30/-	55/-	35/-	75/-
Time to boil.	10 mins.	10 mins.	15 mins. 10 mins.	14 mins.	15 mins.	18 mins.	14 mins.	30mins.	60mins.	25mins.	96mins.	40mins.
Finish‡	Decor. Copper	Copper	Tin	Copper	Copper	Copper	Enamel	Copper	Enamel		Enamel	
Ordinary Cooks' Uten Plain.	3/6	2/-	3/-	5/6	7/-	9/-	2/-	7/-	3/6		6/-	
tto Better Finish	5/-	—	5/-	7/6	—	—	3/6	10/-	5/-		7/6	

Methylated spirit kettle sets are about equal in price to electric kettles, and with spirit at 1/8 per gallon their operating cost is very heavy.

† For total cost of average cooking installations with ordinary heating utensils see Table XII.

‡ The relative costs of utensils in various finishes are, approximately, plain tin: copper: nickel plate: silver plate : : 1 : 1·8 : 2.05 : 2.7.

¶ Portable stove: the other coal ovens are in kitcheners. In connection with the latter the extra cost of fitting and the provision of hot water must be remembered.

VATER BOILERS—URNS, TANKS, GEYSERS.

		GEYSERS.								
ost of Fuel r Energy ‡ per hour.		Type of Heating	Rate of *Boiling* from 60deg. F.	Installation Cost	Consumption	Overall size of Geyser.	Cost of Use per Hour.		Cost per Gallon Water Boiled.	
1.10d.	Kitchen Type. Ornamental	Electric. ("Le Radiant" pattern.)	0.094gall. per min.	£ s. d. 8 0 0	2500 watts	15in. diam. by 25in. high.	2.5d. at 1d. unit.	1.875d. at ¾d. unit.	0.44 at 1d. B.T.U.	0.33 at ¾d. B.T.U.
1.30d.	Fairly Ornamental.									
2.25d.		Oil.	¼gall. per min.	7 19 0	4½ pints per hour	28in. by 14in. by 16¼in.	6.72d.		0.45d.	
4.50d.		Gas.	1gall. per min.	10 8 0	150c.ft. per hour	13in. diam. 35in. high.	4.95d.		0.0083	
0.99d.			¼gall. per min.	7 10 0	100c.ft. per hour	9in. diam. 26in. high.	4.95d.		0.022	
2.64d.										
2.64d.										

If water heated through 40deg. F. is required the above outputs may be multiplied by four.

‡ Electrical energy is taken at 1d. per unit, oil 1/- per gallon, gas at 2/9 per 1000c ft. It is assumed that heating is proceeding at maximum rate possible throughout the hour in each case.

heat regulation possible and the specific output coefficients (viz., the weight and volume per cubic foot heating capacity) are given in Table III. and Fig. 1. The great and irregular variations in the various curves of Fig. 1 are explained by the variety of makes and patterns embodied by the tables. The results in this instance are therefore mainly of value as showing the *order* of the various coefficients.

Costs of Installation and Use.—Before drawing up and explaining the tables of these costs it will be well to state exactly what types of heaters it is proposed to

TABLE VII.—COST OF INSTALLATION—ACCESSORIES.

		£	s.	d.
Electric Radiators:—				
250 watt lamps, 250c.ft. capacity	low voltage, 4s.; high voltage	0	4	6
Guards for ditto	2s. to	0	4	0
Transparent screens (to deflect direct heat)		0	10	0
Wall socket and plug (to carry currents 5A to 15A)	2s. 6d. to	0	3	6
Reflectors	plain, 10s.; D, £1 10s.; D*	3	0	0
Wire from meter to plugs (per yd.) 600 meg.w. silk covered	HV., 1s.; LV.	0	1	3
or, lower grade but sufficiently good	HV., 9d.; LV.	0	1	0
Two or three switches and 3yds. flexible lead included in radiator prices already given.				
Electric Convectors:—				
Heating units (250 watts each)		0	1	6
Ruby lamps (to produce warm glow)		0	1	6
Guard screens, reflectors, &c., unnecessary.				
Necessary heat control switches and flexible wire included as before.				
Steam:—				
Steam mountings for boiler, in 60,000 to 160,000 c.ft. size	£6 10s. to	7	10	0
Steam valves in piping (analogous to electrical main switch, but more costly, besides being supplied by the user instead of by the supply company).				
Diameter of piping: 2in. / 4in. / 6in. / 8in.				
Cost of steam valves: 28s. to 35s. / 62s. to 110s. / 118s. to 142s. / 171s. to		10	18	0
Safety valves suitable for water or L.P. steam	½in., 6s.; 1in., 8/-; 2in.,	0	13	6
For costs of piping, nipples, bends, &c., see curves Fig. 4.				
Drain pipes, &c., too numerous to fully specify.				
Water:—Piping, &c., as in Fig. 4.				
Sockets	7s. to	0	9	0
Rubber rings for ditto	each	0	0	6
Smoke pipe for boiler per yd.		0	7	0
Elbow and door for same		0	10	0
Charcoal Stoves:—				
Gas rings (necessary to ignite fuel)		0	1	6
or Methylated spirit lamps (to ignite fuel)		0	2	0
Gas stoves:—				
Guard (necessary with most types)		0	10	0
Flexible tubing	per ft.	0	0	8
Asbestos fibre	per oz., 10d.; per lb., 5/- to	0	10	0
"Fireproof" bricks	doz.	0	0	6
Fire bricks	each	0	1	6
Damper		0	2	6
Flue elbow		0	3	0
Reflecting "fender"		0	6	6
Base for stoves		0	17	0
Luminous gas heaters:—Burners (for grates)	5/- to	0	8	0
Oil Stoves:—Wicks	per doz. 4/- to	0	6	0

Slow-combustion central-heating coal stoves:—Of these the writer has been able to collect a very complete list of the cost of accessories, which is appended *in extenso.* It will be seen that, in addition to the high prime cost of the stove itself, its great weight and space occupied, the cost of its accessories and means of distribution is very serious. Of course, not all the accessories below would be required in any one installation, but from this data the approximate cost in any particular case can be estimated.

3ft. length fireclay oval pipe, two per stove	5s. to	0	7	6
Cleaning doors (one necessary at every straight length of flue)		0	7	6
Short bend		£0	9	6
Special stoking scuttle		0	8	0
Nozzle from stove to fresh air flue to set up warming and ventilating action		0	12	6
Cast-iron pipe, per foot	1s. 3d. to	0	1	9
Ordinary bends (with cleaning doors, 2s. extra)		0	4	0
Cost of fitting bends (apart from materials)	8s. to	0	9	0
Iron wall nozzle, to take stove pipe		0	4	0
Flange where flue passes through floor		0	6	6
Flange where flue passes through sloping slates		0	6	6
"Bonnet" top for flue		£0	4	0
Wind guard		0	10	6
Compound ridge tile and windguard		1	0	0
Draft regulator (necessary with small stoves)		0	2	6
Ashpan	6s. to	£0	15	0
Descending nozzle and bend		1	0	0
Iron floor bases	32s. 6d. to	2	10	0
Register	average	0	15	0
Valves for gratings		0	9	0
Air inlet pipes	£2 up to	5	0	0
2ft. gilled smoke pipe		0	18	6
Bend for ditto		0	17	6
Room air-inlet valves		1	0	0
Valves to external air		0	15	0
Pilot stoves		2	10	0
Adapting stoves for isolation chambers (for use in motor sheds, &c.) not necessary with electric stoves)	£1 10s. to	2	0	0
Stoking implements (special shapes)		0	5	6

If an underground stoking pit be employed, to this list must be added:

Grating over stoking pit	£1 to £10, say	5	0	0
Ladder into stoking pit		0	10	0
Man-door and frame in grating		1	0	0

On inspecting this list it will be apparent that the auxiliaries of a slow-combustion stove may cost £20 to £30, in addition to the cost of the stove itself.

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compare in each system. The types dealt with are:—

Heaters using coal, coke or charcoal: (*a*) The ordinary domestic grate; (*b*) kitchen ranges; (*c*) slow combustion stoves (using anthracite, charcoal or ordinary coal).

Steam heating systems: Only one system, of medium pressure, is dealt with, steam heating being more applicable to the warming of very large buildings, works, &c., and being therefore treated more fully in a later "Industrial Heating" section.

Water heating systems: The same remarks apply to these as to steam systems, no detailed discrimination being yet made between single and double pipe systems, &c.

Gas heating systems: (*a*) Cooking stoves; (*b*) gas rings; (*c*) room heating stoves; (*d*) geysers.

Oil heating systems: (*a*) Room heating stoves; (*b*) cooking stoves.

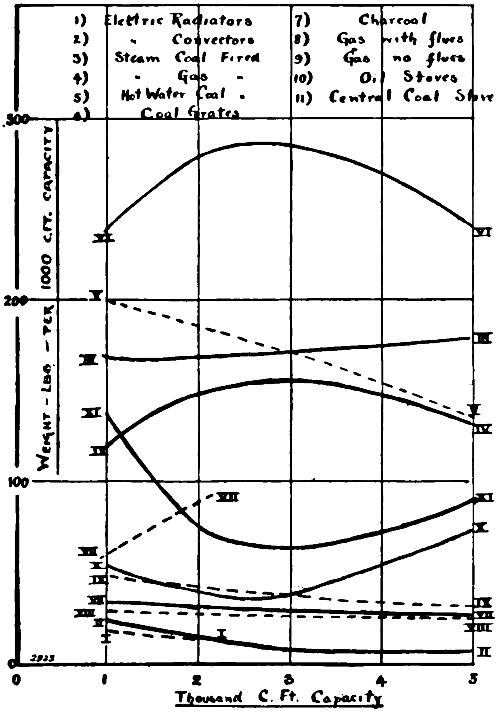

FIG. 1.

Electric heating systems: (*a*) Radiator heaters; (*b*) convector heaters; (*c*) enamel embedded heaters. Since electrical apparatus is not so familiar to the general public as that of the other heating systems, it may be well to define exactly what is meant by the above three types of electrical heaters, the advantages of each being considered later. Radiators are practically glorified electric glow lamps in which the filament (at present universally of carbon) is run at a lower temperature than in a lighting lamp, so that, at the lower temperature, the value of the ratio of heat energy emitted to total energy emitted is higher than in the case of a unit used for lighting. The curve Fig. 2 shows the relation between temperature of filament and percentage of heat to the total energy radiated. It is desirable to run the filament at such a a temperature that it emits an orange-red light, in order to obtain a cheerful appearance. Carbon is superior to metal filaments for radiators for precisely that reason which makes it inferior to the latter for lighting, viz., the fact that, at a given temperature, the carbon filament dissipates a higher percentage of the energy supplied to it as heat than does the metallic filament. (Thus the percentage of visible to total radiation was 3.2 per cent. for a good carbon lamp, but

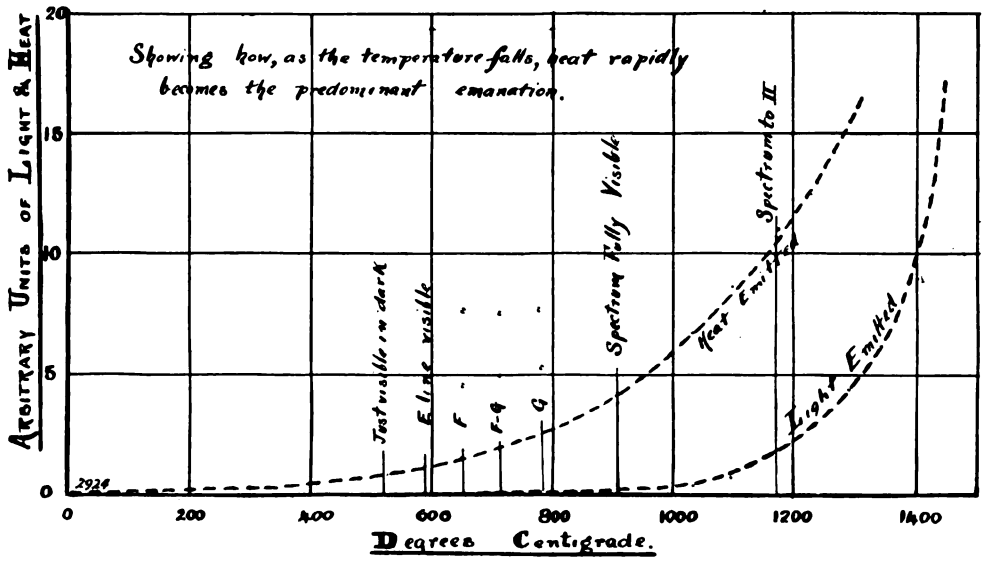

FIG. 2.

9.1 per cent. for an Osram lamp.) At the low working temperature employed the life of the carbon filament is very long, disintegration of the filament being practically nil. Radiators are very applicable to certain classes of work, and are so named in consequence of their heating effect being mainly by radiation. The fact that the heating is so produced explains their particular applications given later. Convectors consist of metal resistance strips not enclosed from the air in any way. The strips are so designed as to run at quite a low temperature (usually about 260deg. F.), and hence their life is very long, being chiefly determined by atmospheric corrosion and accidental mechanical injury. As their name denotes, these heaters depend chiefly on convection for their effect. Enamel-embedded heating units are run at a higher temperature than convector strips, and are chiefly used in cooking utensils; they supply heat by conduction in saucepans, &c., and by combined convection and radiation in ovens.

R. E. NEALE.

(*To be continued.*)

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ELECTRICAL EARTHQUAKES.

The following letter, which appeared recently in a Yorkshire daily contemporary, opens up a field of electrical energy hitherto neglected by the electrical engineer, and incidentally reveals a method of preventing earthquakes. We cannot recommend a trial of the system advocated—the two-fold disappointment in failure to accomplish such glorious results might be disastrous.

Some scientific men are inclined to believe in the theory that some earthquakes are caused by the accumulations of electricity in the earth being excited, agitated, and perhaps liberated by the attraction of the moon pulling the same way and at the same time as the sun, and perhaps also some planet or planets, or possibly a comet also, though some local earth-shakings are caused by the slipping, sliding, bending, or breaking or fracturing of the strata of rocks. We must now consider that electricity is being manufactured or drawn to us (though most of us do not know what it really is, nor where it comes from, nor where it goes to, although we have found out the way of getting it or drawing it to us and storing it) in great quantities for power, message, and light, instead of steam and gas, and that much of this electricity escapes somewhere, probably into the earth to some place or places which attract it or allow it to accumulate, and that this quantity is now and ever will be on the increase. Why may not some of this largely increased volume of electric fluid be flying to the weakest spots in the earth's crust, which are known as places where great earthquakes have taken place in modern and ancient times? Therefore it may be worthy the consideration of people who may be interested in the subject to try to find out a way whereby some earthquakes (perhaps foretold) can be prevented, or the effects considerably lessened, by men boring down into the earth, and putting down good conductors of electricity—water, or, say, copper wire or wires—and then taking the other end or ends of the wire or wires and dropping them into the sea or some great sheet of water which is a good conductor, and so let the fluid pass away without doing damage, or perhaps at some future time some of this earthquake electricity may be caught and stored for man's use, and so be made his servant instead of being his master.

THE WORKING AND TESTING OF POLYPHASE SYNCHRONOUS MOTORS.

As is well known, a polyphase synchronous motor is simply a polyphase generator reversed, which when supplied with alternating currents may be used as a motor. Such a motor will have field magnets of constant polarity, these being separately excited from a source of direct current as in the case of an alternating-current generator. A synchronous motor will exert no driving torque until it runs at its synchronous speed, which equals frequency × 120 ÷ number of poles; it is therefore necessary to run such a machine up to speed by external means before switching on the supply current, and should the speed by any means fall below that of synchronism the motor would stop, for reasons to be explained later on. For such a motor to exert any driving torque it is necessary that the frequency of the supply current be the same as that of the e.m.f. generated in its armature, the value of the frequency being given by r.p.m. × number of poles ÷ 120. When the frequency of the supply current is at its correct value, the direction of the current in any particular armature conductor at any instant will be reversed as that conductor passes from a field of one polarity into a field of opposite polarity. In other words, if the machine is to exert a constant driving torque, the reversal of the current in each conductor must take place at the same time as that conductor is moving from one pole to the next. As a synchronous motor is only capable of exerting a driving torque at one definite speed, which is quite independent of its field strength and supply voltage, the relation between the mechanical load on the motor and its electrical input corresponding to that load does not depend upon the ratio of the supply voltage to the counter e.m.f. of the motor, as is the case with a direct-current machine, but is governed by the phase relation existing between them.

When considering the operating characteristics of a synchronous motor it is necessary to take into account (1) the e.m.f. impressed on the motor, (2) the counter e.m.f., (3) the resultant of these two e.m.f.'s, (4) armature impedance and current. The counter e.m.f. of the motor will be alternating and opposed to the impressed e.m.f., the adjustment of the armature current required by a change in the load on the motor being due to the change in the magnitude of the resultant of the counter and impressed e.m.f.'s. As the speed of the motor remains constant at all loads it has no effect on the counter e.m.f., the change in the armature current at different loads being caused by an alteration in the phase difference between it and the impressed e.m.f., which alters the value of the resultant e.m.f. The working of a synchronous motor may be shown graphically by the vector diagrams in Fig. 1, which represent the current and e.m.f. relations with a given excitation and constant impressed e.m.f (*a*) at no load, (*b*) for an increasing load, and (*c*) for a decreasing load. Referring to the diagram (*a*), let OE represent the voltage impressed on the motor terminals, and OV the counter e.m.f. of the motor at no-load, then the resultant of these two e.m.f.'s OR represents the voltage available for overcoming the armature impedance. The resultant e.m.f. in a synchronous motor is the difference between the impressed e.m.f. and that part of the counter e.m.f. which is in phase with the impressed voltage.

The vector OR_1 is also the resultant of

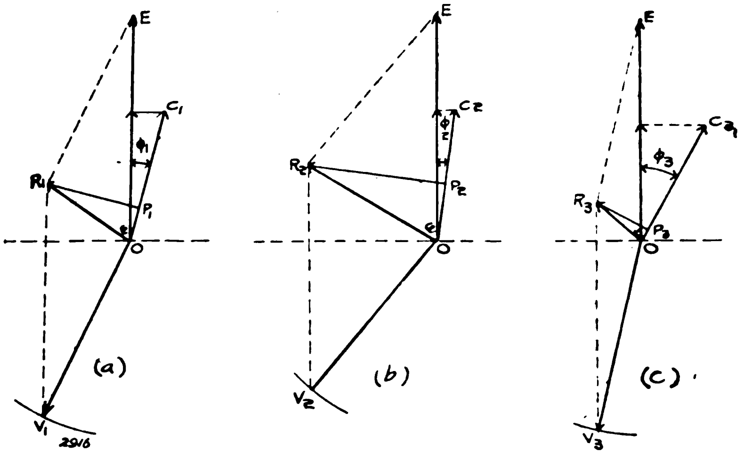


Fig. 1.

the resistance and reactance drops of the armature, these two quantities being represented by OP_1 and P_1R_1 respectively, the angle ϕ being such that tan ϕ = armature reactance ÷ armature resistance. The armature current which is given by resultant e.m.f. ÷ impedance is represented by the vector OC_1, being in phase with the resistance drop, and the angle of lag of the armature current behind the impressed voltage will be given by ϕ_1. This represents the current and e.m.f. relations of the motor when running on light load. When an increase in the load takes place, the vector representing the back e.m.f. (which remains constant at all loads) swings backwards in a clockwise direction, taking up the position OV_2 in diagram (*b*), thus working itself more out of phase with the impressed voltage. The resultant e.m.f., OR_2, will now be increased sufficiently to allow of an increase in the armature current OC_2 required by the increased load. The angle of lag of the current behind the impressed voltage is now ϕ_2, and it will be noticed that as the load increases, these two quantities are brought more nearly into phase; that is to say, an increase of load on a synchronous motor increases its power factor to a certain extent, without any adjustments of its excitation. When the load on the motor decreases, the vector representing its counter e.m.f. moves round in a counter-clockwise direction, finally taking up the position OV_3 in diagram (*c*) and thus gradually gaining in phase on OE. The resultant e.m.f. represented by OR_3 will now be reduced, the armature current OC_3 being decreased in proportion. The balance between the impressed voltage and the counter e.m.f., which is upset at every change in the load, is really maintained by armature reaction, the phase relation between the armature current and the counter e.m.f. being varied so that the effect of the former is either to magnetize or demagnetize the field as required.

When the load on a synchronous motor increases there is a momentary drop in its speed, and this causes its armature to take up a new position which alters the phase relation between the counter and impressed e.m.f.'s, so that the former offers less opposition to the latter; consequently the armature current will be proportionally increased. When the load decreases a reversed effect takes place, so that the armature current automatically adjusts itself as regards its magnitude and phase relation to the value required by any particular load on the motor, and when this is the case the motor is said to be running under stable conditions, so far as its operating characteristics are concerned. As regards the excitation of synchronous motors, it is a well-known fact that it is possible to work at any power factor by altering the field strength, and this question may be considered as follows. When the excitation on a motor is such that the impressed voltage =

$$\sqrt{(\text{Counter e.m.f.}^2 + \text{CR drop}^2 + \text{reactive drop}^2)}$$

the armature current will be exactly in phase with it, the power factor will be practically

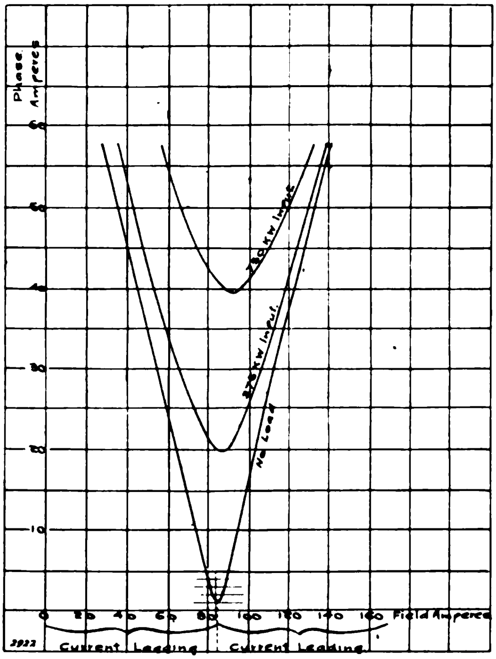


FIG. 2.

unity, and the current input to the motor will be a minimum. Any further increase in the excitation above this point will give rise to a leading current, which will cause the current input required for any particular load to increase. It follows, therefore, that every load has its corresponding value of excitation which enables the motor to work with the smallest armature current. This variation of the armature current with the exciting current is one of the most important characteristics of the synchronous motor, and the curve representing such variation is, owing to its shape, known as a V curve.

Having considered the working of synchronous motors, a brief description of the shop tests generally carried out on these machines may be of interest. These tests may be classified under two distinct heads, viz., experimental and commercial. The experimental tests carried out are (1) resistance; (2) open and short circuit characteristics; (3) iron loss, saturation and friction; (4) efficiency; (5) regulation and V curves. It will be seen that these tests are practically the same as those made on alternating-current generators, and with the exception of the tests for regulation and V curves, are carried out in the same manner, and as the testing of generators has already been considered in a previous article (see THE ELECTRICAL MAGAZINE, September, 1908) it will only be necessary to describe these latter tests.

The regulation of a synchronous motor shows the relation between the field amperes and armature amperes at unity power-factor, and is carried out in the following manner. The synchronous motor is belted to a direct-current generator of sufficient capacity to transmit the full load of the former when run on a rack load. The test is started by running the synchronous motor up to speed by means of the direct-current machine, which is connected to a suitable source of supply and run as a motor for this purpose. After the synchronous motor has been synchronized and connected to the alternating-current supply, the direct-current machine is disconnected from the supply circuit

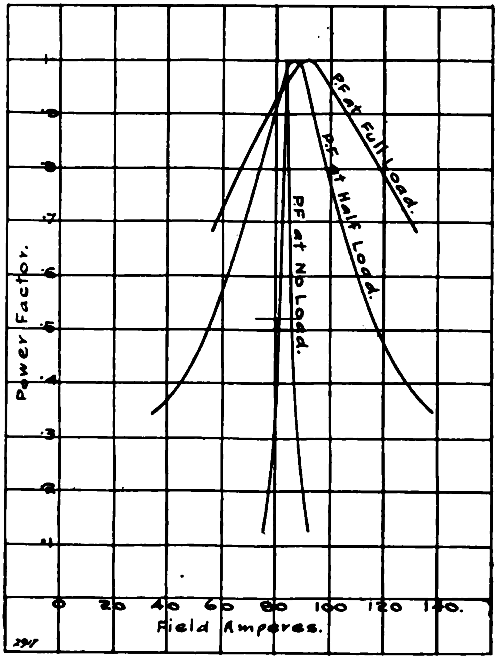


FIG. 3.

and connected as a generator to the resistance rack. A series of readings of the field and armature amperes on the motor is then taken at different loads, the power factor being held at unity by varying the exciting current until the armature current reaches its lowest value, this adjustment of the exciting current being made for each load on the motor. From the results of this test a curve is plotted having armature amperes as abscissæ and field amperes as ordinates. The frequency and supply voltage must be held constant during this test, and the data obtained enable the efficiency to be worked up in the same manner as with an alternator.

The data for the V curves are obtained by running the motor on no load, half load, and full load at different exciting currents, and taking readings of armature and field amperes. A reference to the series of V curves shown in Fig. 2 which were obtained from a 1000h.p. 11,000-volt Westinghouse three-phase motor, shows that the armature current varies to a greater extent, also that the curve is more V-shaped at no load than is the case when the motor is loaded, and that the variations in armature current for any particular values of exciting current decrease as the load increases. When the power factor of the motor is unity, the apparent watts will be equal to the true watts input, and as the terminal voltage has a constant value, the value of the input armature current may be taken as a measure of the power factor, so that it is possible to calculate the power factor from the data given by the V curves, and this has been done for the different loads on the motor in the following manner. The full-load rating of the motor is 1000h.p., which corresponds to 750k.v.a.

$\therefore$ full-load current is given by

$$\frac{750 \times 1000}{11{,}000 \times \sqrt{3}} = 39.4\text{amp. per phase, and}$$

it will be seen that this corresponds to the current input at unity power factor on the V curve at full load, so that in this case the ratio $\frac{\text{true input current}}{\text{actual input current}} = \frac{39.4}{39.4} = 1$, and this corresponds to an exciting current of 92amp. Taking another point on the curve, namely 45amp., its corresponding power factor $= \frac{39.4}{45} = .875$, the other points being found in a similar manner. The results of these calculations at full, half and no load, are given in Tables I., II., and III. respectively, and are also shown by the curves in Fig. 3. The curve representing the power factor at no load shows very plainly how widely it varies for different values of the exciting current when a motor is running light. The saturation and short-circuit curves of this machine are shown in Figs. 4 and 5 respectively.

TABLE I.

Power Factor at Full Load.	Exciting Current.	
	Armature Current Lagging.	Armature Current Leading.
1.0000	92 amperes current in phase.	
0.9850	88	96
0.9275	80	104
0.8750	74	110
0.7880	66	120
0.7230	60	127
0.6860	57	132

TABLE II.

Power Factor at Half Load.	Exciting Current.	
	Armature Current Lagging.	Armature Current Leading.
1.0000	86 amperes current in phase.	
0.9850	84	90.0
0.9160	80	93.0
0.7875	73	99.0
0.5725	60	112.0
0.4925	54	118.5
0.3720	40	134.0
0.3430	35	138.5

TABLE III.

Power Factor at No Load.	Exciting Current.	
	Armature Current Lagging.	Armature Current Leading.
1.000	84 amperes current in phase.	
0.768	83	85.5
0.500	82	86.5
0.280	80	88.5
0.125	76	92.5

The regulation curve of this motor, when run as a generator at unity power factor and a constant exciting current, is shown in Fig. 6; and the curve, Fig. 7, represents its efficiency as worked up from the losses, but neglecting the loss due to friction and windage.

As regards the commercial testing of synchronous motors, the tests generally made are those of (1) polarity, (2) temperature, (3) insulation. The temperature test is made by belting the machine to a direct-current generator of suitable capacity, and is carried out in a similar manner to a regulation test, with the exception that the load is held constant throughout the test. So far as the polarity and insulation tests are concerned, the remarks made in connection with these tests when carried out on alternating-current generators apply as well to synchronous motors.

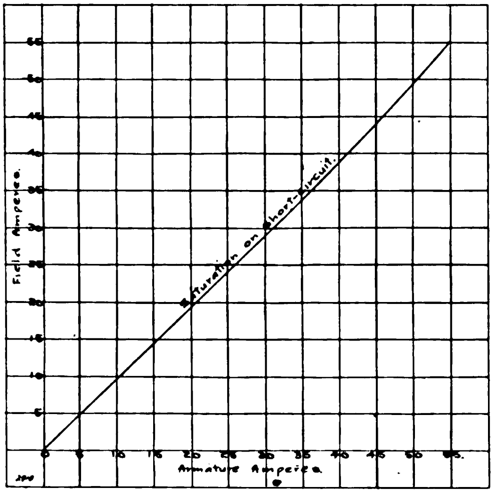


FIG. 4.

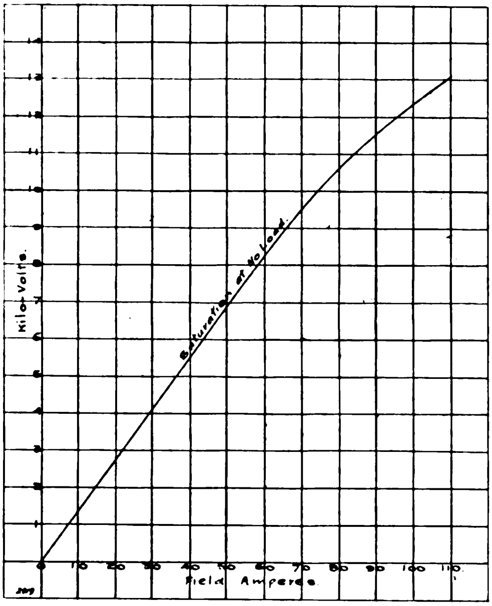


FIG. 5.

As the operating characteristics of the induction type of motor have also been considered in these columns, it will be at least of interest to make a comparison of both types. The operating characteristics of both types of motors, between which a comparison should be made, are those of: (1) Starting and running, (2) maximum and starting torques, (3) speed control, (4) current consumption, (5) power factor, (6) reaction effects on the supply circuit, (7) overload capacity. These characteristics may be considered as follows:—

Starting and Running.—A synchronous motor requires a separate source of mechanical power to start it up, also some form of friction clutch must be put between the motor and its load, as it cannot be started under load. On the other hand, an induction motor is started by simply throwing a switch to the starting and then the running position, and as it is capable of starting under load, it requires no friction clutch or starting motor.

Starting and Maximum Torque.—In

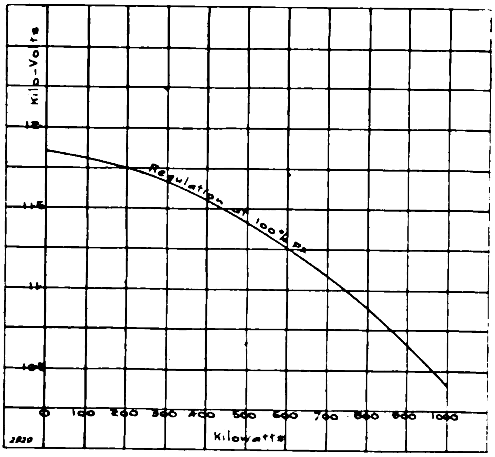


Fig. 6.

practice a synchronous motor is run up to its speed of synchronism by means of a starting motor of which the starting torque is very small, but although a synchronous motor has no starting torque, it has a maximum torque which exists at its synchronous speed. With an induction motor the starting torque is very large, being generally about three times the value of its full-load torque, and by means of an external resistance in the rotor circuit it may be adjusted to suit the load against which it has to start. Its maximum torque is higher than that of a synchronous motor, and increases with a decrease in the speed. In the case of the latter type of motor, however, a decrease in the speed due to an overload would cause the torque to fall off very rapidly, finally stopping the motor.

Speed Control.—A synchronous motor has but one definite speed at which it can develop a driving torque, whereas an induction motor may be designed to work at a practically constant speed, or develop large torques over a variable range in speed.

Current Consumption. — The operating current taken by a synchronous motor depends upon its excitation, and requires constant adjustment to keep it at an economical value when working on a varying load. In the case of an induction motor the current is proportional to, and automatically varies with the load on the motor, and is quite independent of the control of the operator.

Power Factor.—The only advantage the synchronous has over the induction type of motor lies in the fact that it is possible, generally speaking, to raise its power factor to unity by adjusting its excitation; but under some operating conditions its power factor may be less than that of an induction motor. Owing to the fact that an induction motor always takes a lagging current its power factor is not very high, and varies in proportion to the load. At any particular load, however, it has a definite value which is not under the control of the operator.

Reaction Effects on the Supply Circuit.—The periodic fluctuations in the speed and armature current, known as "hunting," which are sometimes set up in a synchronous motor, have an effect on the generators as well as other motors connected to the circuit. They also affect the voltage drop in the system, the voltage of which is dependent on the adjustments required for the satisfactory working of the motor. The only bad effect an induction motor has upon the system is to increase the voltage drop due to the lagging currents it introduces into the circuit, but as these currents have a definite value, being constant at any particular load,

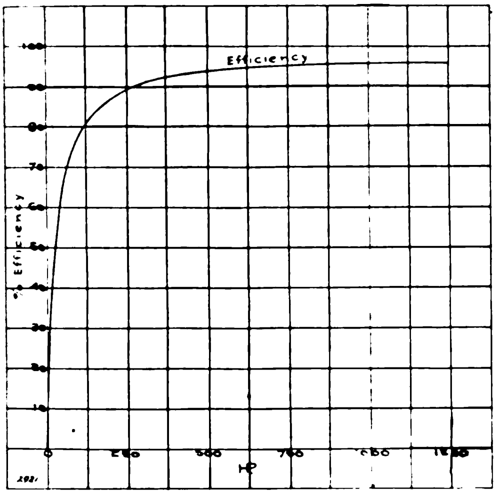


Fig. 7.

it is not difficult to keep the voltage of the system under control.

Overload Capacity. — Any momentary increase in load on a synchronous motor will cause it to fall out of synchronism and stop, and a sudden increase in the generator speed is likely to have a similar effect if the motor happens to be working at or near its full capacity. In the case of an induction motor, a sudden increase in the load will simply cause a momentary drop in speed which will again rise to its normal value when the overload is removed.

From the above comparison of both types of motors it will be seen that although it is possible to vary the power factor of the current supplied to a synchronous motor, it has several serious disadvantages which make it less satisfactory to operate than the induction type of motor.

In conclusion the writer's thanks are due to the British Westinghouse Company for their kindness in supplying curves and data of their synchronous motors.

J. W. ROGERS.

* * *

A COMPARISON BETWEEN GAS AND STEAM ENGINES FOR THE GENERATION OF ELECTRICITY.

It is only in the last few years that large gas engine sets have been used in electrical generating stations. A generating station equipped with water tube boilers, superheaters, high-class compound steam engines, economisers, and coal handling plant will cost practically the same amount as a gas engine set, with gas producers and ammonia recovery apparatus, both costing about £22 10s. per k.w. Also both stations would require the same amount of ground space.

With steam plant there is a greater loss due to radiation because the temperature of the gases in the steam pipes is higher than those in he gas engine pipes. At the slack times a gas producer can be banked much more economically than a steam boiler can, and when a set is shut down all the auxiliaries can be stopped as well, but with a steam engine the feed pump and other auxiliaries have to be kept going. The "load factor" greatly affects the question, as the gas engine is far more economical on the lower load factors.

If the producer plant be greater than say 2500h.p. it is profitable to recover the sulphate of ammonia from the producer waste.

The gas engine has one great drawback, and that is it will not meet an overload, and another set has to be started up, whereas a good steam engine will supply an overload of 20 per cent. Further, the gas engines are liable to produce very excessive vibration when they backfire.

The cost of attendance, cleaning, depreciation, &c., will be about equal in each case. A steam engine set will require four times the quantity of water that a gas engine will, an item of considerable importance where the water supply is expensive. The efficiency of large gas engine sets has been greatly increased during the last five years and the gas engine is rapidly becoming a serious rival to the reciprocating steam engine.

S. M. HILLS.

THE FORTH BANKS WORKS OF MESSRS. R. & W. HAWTHORN, LESLIE & CO., LTD.

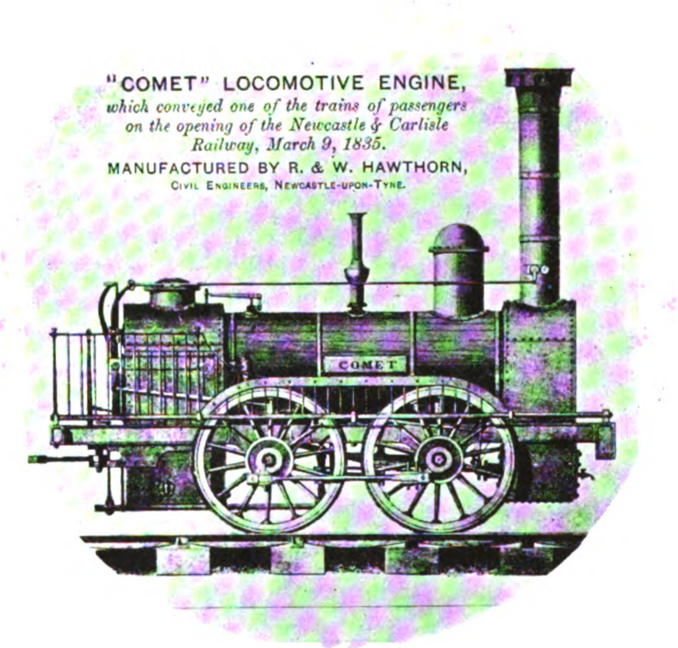
TWO years after the battle of Waterloo, namely, in 1817, Mr. Robert Hawthorn took an open shed at the west side of the Forth banks, and commenced to manufacture steam engines, mill work, and the like. He had four workmen, and, what is more, retained them for a lifetime of service. In two years, by dint of hard working side by side with his men, the founder of the firm was able to buy a small portion of the ground on which the present works stand. In the evenings, after work hours, the master and his men, now numbering twenty, excavated the hill-side and prepared for the building of the first shop with their own hands.

In 1820 the pay roll had lengthened to thirty-four, Mr. William Hawthorn became partner with his brother, and about this time the young firm built the first self-acting steam crane for delivering ballast from ships, which was erected on the banks of the Tyne.

At the end of the year 1822 the motive power of the firm was changed over to steam. This change was rendered necessary by the fact that the growing operations of the firm rendered the method of driving the lathes by means of men turning a hand-wheel rather obsolete. In these latter days, it may be remarked, steam has in its turn been ousted in favour of electricity. The firm was distinctly progressive, scoring several successes in the production of novelties. In 1824 it made a 50h.p. engine, which was a colossal size in those days. In 1829 was produced a 6h.p. road tractor, one of the earliest prototypes of our steam delivery wagons. In its travel along the main turnpike from Newcastle to Sunderland it created much excitement. In 1831 a locomotive was built; in 1834 the first Cornish pumping engine in the district was made by the firm, and on the 9th March, 1835, when the Newcastle and Carlisle Railway was opened, the "Comet," made by R. and W. Hawthorn, was one of the locomotives that shared in the inauguration. This engine, by the way, after its period of service on the railway, drove the wood-working machinery for the firm. To summarise the further progress of the firm, marine engineering was also undertaken, and was transferred in the early eighties to the present extensive works at St. Peter's-on-Tyne. In 1883-4 the firm acquired the shipyard of Mr. Andrew Leslie, at Hebburn-on-Tyne, and the firm has since been known as R. and W. Hawthorn, Leslie & Co., Ltd. Its history has been one of continuous expansion, the present locomotive works having extended to a very large proportion of the former works of Messrs. Robert Stephenson & Co., Ltd., which they adjoined, and for a period of about seventy-five years the two firms worked side by side.

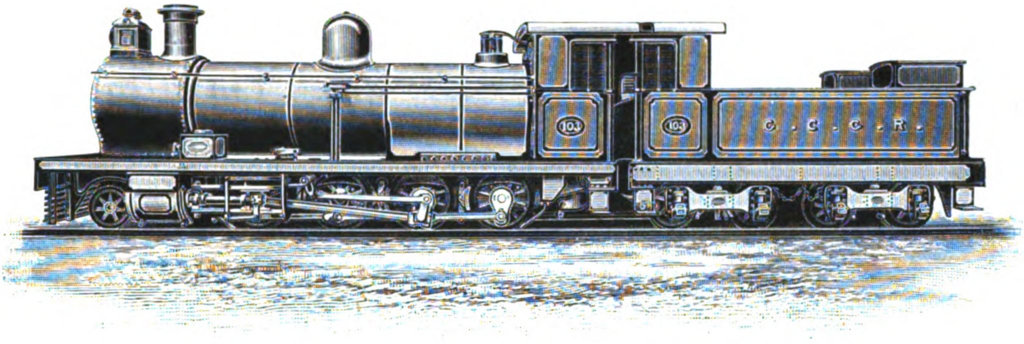
The works are in close proximity to the North Eastern Railway, to which they are connected by sidings. The traffic is worked by one of Messrs. R. and W. Hawthorn, Leslie & Co.'s combined crane locomotives, which is one of their important specialities, and some interesting particulars of which are as follows:—

It has great advantages in saving time and labour. For carrying material from place to place, loading and unloading wagons, in addition to the powerful locomotive hauling and shunting the traffic, it is unequalled. The crane is worked by the direct action of steam on the jib, which lifts 2 tons at a distance of 20ft. from the centre of the railway, 3 tons at 16ft., and 4 tons at 12ft. The load is slewed to any part of the circle by a two-cylinder turning engine, the whole being under the control of the driver. These engines are now most successfully used by many of the largest firms in this country, British and foreign Government dockyards, and are especially adaptable for use in shipbuilding yards, iron and steel works, dock quays, and railway goods depots, and in many places where large quantities of goods have to be handled in railway trucks.



"COMET" LOCOMOTIVE ENGINE,
which conveyed one of the trains of passengers on the opening of the Newcastle & Carlisle Railway, March 9, 1835.
MANUFACTURED BY R. & W. HAWTHORN,
CIVIL ENGINEERS, NEWCASTLE-UPON-TYNE.

A prominent feature in the operation of this old-established firm is the wholesale adoption of electricity for lighting and power, which has entirely displaced steam power. A supply of electricity by means of continuous current is obtained from the mains of the Newcastle and District Electric Lighting Company, Ltd., at a pressure of 480 volts, and no stand-by provision is made for the breakdown of electricity supply, inasmuch as the result of the adoption of electric power has been uniformly successful. The works provide a very heavy load factor and subjects the system to a fair test as regards reliability, frequently running night and day. Motors ranging in capacity from 10 to 120h.p. are installed, and, as a rule, group driving is adopted. In the case, however, of some of the heavier machines the power demand is so great that separate motors are installed. The supply of electricity displaced a collection of isolated steam boilers and engines, and economy has been obtained, not only in the cost of fuel and upkeep, but also in labour required. The single duty of bringing coal and removing ashes to and from these boilers was in itself an expensive item. Moreover, it used to be necessary for men to come in late on Sunday night in order to raise steam for the beginning of the week, whereas now there is no necessity for such extra time to be worked; and the trouble of smoke nuisance, inevitable in a closely-crowded neighbourhood, was also felt.



Modern Hawthorn-Leslie Locomotive as supplied to the Gold Coast.

Turning now to the general equipment and operations of the firm, the locomotive erecting and machine shop, and also the extensive boiler shop at Forth Banks, are fitted with first-class machinery admirably adapted for locomotive work of the most modern class and for the largest engines. Locomotives are constructed here for all parts of the world, comprising foreign and colonial railways, and in addition to this there is done a very considerable home trade.

A very large and important branch of the works is devoted to the manufacture of water-tube boilers of the varied classes which are and have been used in the British and foreign navies, and those which are most largely constructed now are of the Yarrow types, for war vessels and first-class battleships and various types of cruisers and destroyers. These are built for the firm's large naval marine engine works at St. Peter's-on-Tyne, which are constantly engaged in engining the largest class of war vessels for the British and foreign navies, including cruisers and destroyers. The most recent practice for war vessels, from first-class battleships to cruisers and destroyers, are turbines, for the manufacture of which the firm have built special works.

The firm also build all types of torpedo vessels and destroyers at the Hebburn shipbuilding yard, in conjunction with their other works, and some of the fastest vessels of these types ever constructed are and have been turned out at these works, including the celebrated *Viper*.

A notable feature of the Forth Banks works is the extensive use of compressed air, which is distributed throughout the shops for the purposes of drilling, chipping, caulking, tube expanding, and other processes, and the compressor for which is operated electrically from a most interesting installation.

The works and offices are electrically lighted throughout by flame and ordinary type open arcs, and also enclosed arc lamps, while for the purpose of lighting individual machines incandescent lamps are used.

It will be seen from the above description that these high-class and extensive engineering works have been developed from the small beginnings described above by a continuous process of intelligent enterprise until they now rank among the most important of their class in England, and it is gratifying to electrical engineers to know that a firm of such experience should place such confidence in electrical drive that they do not consider it necessary to provide an alternative source of power for their works to that given by the Newcastle and District Electric Lighting Company, Ltd., whose steady engineering progress is well known.

J. A. Seager.

ELECTRICAL MEASURING AND TESTING INSTRUMENTS.

(*Continued.*)

For extra high pressures, say above 20,000 volts, one of the latest types of electrostatic voltmeters is that of Jona, which Messrs. Everett, Edgcumbe have placed on the market in this country. In this pattern, with which pressures up to 200,000 volts may be measured, it is obvious that very special precautions have to be taken as regards insulation, to prevent the instrument itself reading inaccurately, due to leakage or breaking down at weak points, and also to ensure perfect safety to the operator. The general appearance of the instrument is shown in Fig. 10, whilst a sectional view is given in Fig. 11.

The pressure to be measured is applied to the two terminals A and B, of which the former is connected to a sheet of tin-foil on the outside of the stout cylindrical glass vessel D, and, when electrified, this plate induces a charge on another tin-foil sheet, E, on the inner side of the glass The terminal B is in metallic contact, through the supporting strip K, with the suspended and movable plate, C, of the measuring system. C is connected to the index and is suspended by the metallic strip from one end of an arm, the other end being attached to a spindle pivoted, in the usual manner, in jewel bearings, and having a pointer and scale. C is, therefore, attracted by E with a force which is dependent on the pressure, and its value can consequently be read on the scale at F.

The fixed and movable plates are immersed in transparent insulating oil, which nearly fills the vessel D. The presence of the oil both damps the oscillations, ensuring deadbeatness, and prevents danger of sparking across. Since the attractive force depends on the nature of the oil, the instrument is calibrated with that oil which is subsequently to be used.

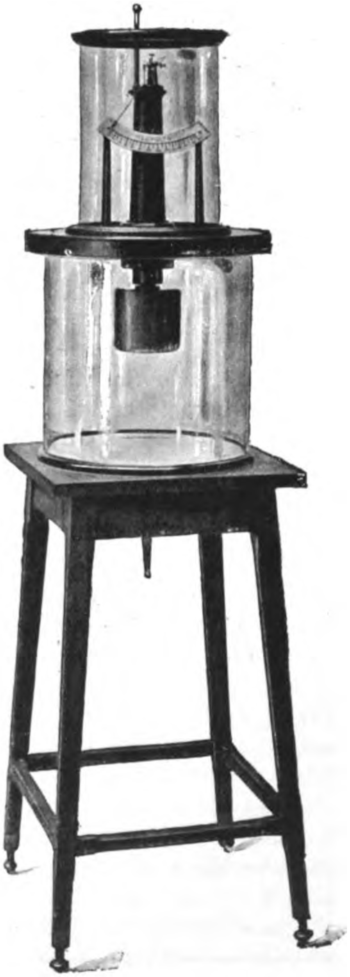


FIG. 10. THE JONA ELECTROSTATIC VOLTMETER FOR EXTRA HIGH TENSIONS.

The light movable plate C is surrounded by and is in metallic connection with a metal shield or protector, G, which is, therefore, at the same potential, and which effectively prevents any external electrostatic fields from interfering with the accuracy of the readings.

There is an adjustable controlling weight, H—a pair of weights are usually provided, which give two sensibilities, the one double the other. The scale is almost evenly divided through the working range.

A new frequency recorder just introduced by Messrs. Everett, Edgcumbe has for its chief working parts a small series motor direct-coupled to a small magneto-dynamo. The combination is such that the motor running with plain iron armature keeps synchronism with the alternating-current supply, and the magneto gives voltages which are directly proportional to the speed, *i.e.*, to the frequency, and these are recorded in the usual manner by a recording voltmeter.

The important part is the neat adaptation of a change-over switch by means of which the small motor-generator set is brought up to speed as a series motor on the alternating-current main, the changing over of the switch cutting out the winding on the rotating iron armature, and, of course, leaving the set running in synchronism as a simple iron armature synchronous motor.

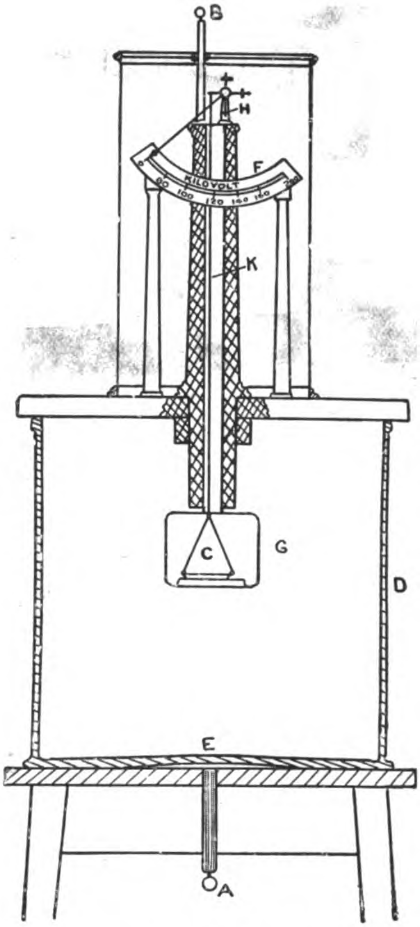


FIG. 11.* SECTION OF THE JONA ELECTROSTATIC VOLTMETER.

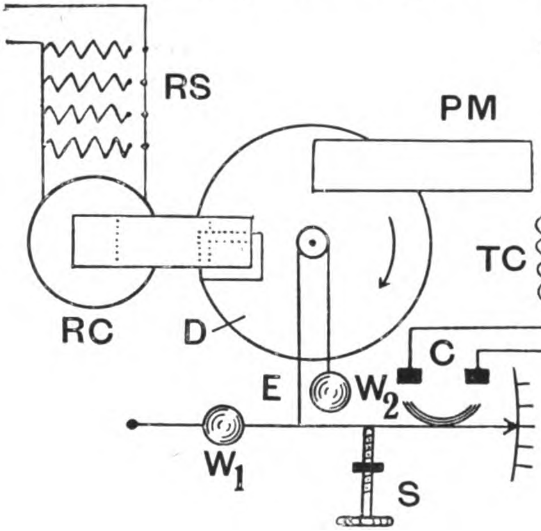


FIG. 12.* TIME-ELEMENT SWITCHBOARD RELAY.

The importance of relays as switchboard accessories is becoming so great that a form of alternating-current overload relay lately placed upon the market by this firm cannot well be passed over. It is based on the induction

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* Illustrations by permission of Messrs. Constable & Co.

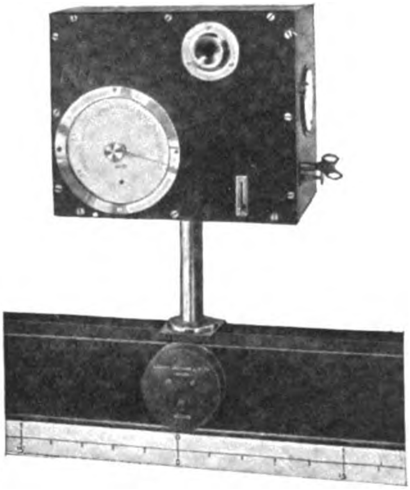

Fig. 13. Flicker Type Photometer Head.

principle and is shown diagrammatically in Fig. 12. A shaded-pole electro-magnet RC urges a disc D in the direction indicated, and a weight W_2 keeps tight a cord E which passes round the spindle. The pivoted arm carrying the weight W_1 and the contact C is thus raised, until the circuit is closed by the latter. A permanent magnet PM induces Foucault or eddy currents in the moving disc D, and thus retards its motion. Consequently, the heavier the overload, the more rapidly the disc rotates. The time-lag at any particular overload can be altered by varying the travel of the contact lever by means of a small screw S.

A distinct advantage possessed by this method is that the time curves are absolutely identical for all time settings. This is essential if discriminating action is to be obtained, as, with those relays in which the regulation is performed by varying the damping, the time curves show a tendency to meet at a point corresponding to some three or four times the normal full load, because of the disc reaching a synchronous speed which is not exceeded, however great the overload, so that, whatever may have been their time settings, two relays in series may go off in the wrong order, which, of course, is fatal. To mention an example, in the event of an earth on a feeder the circuit-breaker controlling it must open before that on the generator, otherwise all the feeders would be shut down.

The relay is also so constructed that it works at a constant induction throughout, so that the curves for various current settings are also identical. The current setting is carried out by means of adjustable shunts, RS, any one of which can be joined in parallel with RC by means of a plug. If the regulation were performed by varying the control weight, the curves would vary considerably, owing to the saturation of the core.

In view of the industrial importance of accurate photometry, instrument manufacturers have given, during the last few years, a good deal of attention to the production of apparatus of the greatest reliability and refinement. Accurate work has become of the greatest practical and commercial importance. An obvious example is furnished by the contemporary rivalry between the conflicting interests of gas and electricity undertakings.

The Everett-Edgcumbe combined flicker and inclined screen photometer head (Fig. 13) possesses all the advantages of the flicker head in addition to those of the contrast type. In fact, it can be used either as a flicker photometer or as an inclined screen photometer. A sectional view is shown in Fig. 14. Light from the standard lamp falls on a screen, which may be either rotating or stationary, according to whether it is being used as a flicker photometer or not.

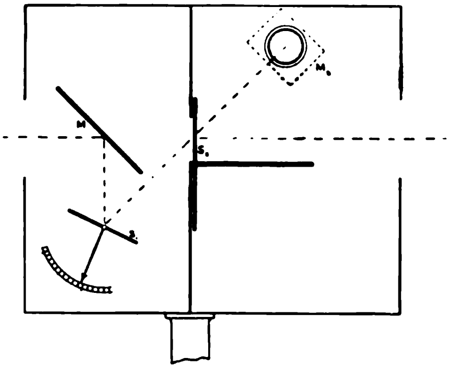

Fig. 14. Section of Flicker Photometer Head.

The adjustable screen at the same time receives light from the comparison lamp. An important feature is that the adjustment can be made either by varying the distance of the lights from the photometer in the ordinary way, or by altering the angle of one of the two illuminated screens. Thus, instead of having to move a comparatively heavy mass, the final adjustment can be made by means of a light milled head on the photometer itself. Further, the rays of light from the lamp under test strike the photometer screen perpendicularly, so that angularity errors are entirely avoided. The adjustable screen also greatly increases the possible range of measurement. Amongst the many applications of this apparatus may be mentioned the following: the scale can be used to indicate the percentage by which a number of lamps differ from a particular standard; also in the photometry of very high candle-power lamps, the illumination received from them can be reduced in any required proportion by adjusting the movable screen, and by this means they can be balanced against an ordinary standard lamp even in a photometer room of restricted size.

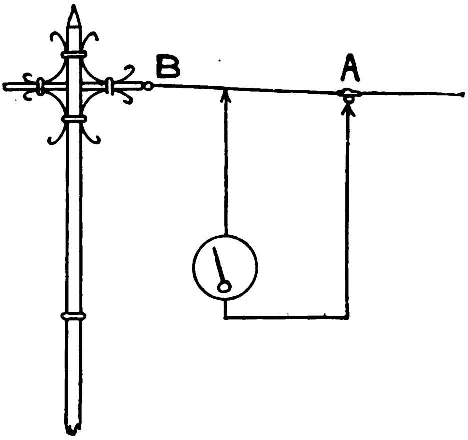

Fig. 16. Principle of Trolley Insulator Tester.

The chief features of a new workshop potentiometer, introduced by this firm, are its portability and its compactness. The ordinary potentiometer is too cumbersome and refined for workshop use. This instrument has been designed for such work as checking ammeters, voltmeters, and wattmeters on site, and also for photometer work. One of the new patterns is designed specially for the latter work, and has three current ranges for maxima of .3, 1.5, and 6amp., and volt ranges of 75, 150, and 300 volts. The galvanometer supplied is amply sensitive enough for all ordinary commercial work, and is self-contained in the case. The slide wire, which is circular, gives a scale roughly 12in. long, and in series with this are 14 similar coils, so that the effective scale length is about 15ft. The cadmium or Clark cell contained in the case is readily removable. Various shunts can be supplied, thus extending the range of the instrument to any required degree. If in any special cases additional sensibility is required provision is made whereby an external reflecting galvanometer can be employed at will.

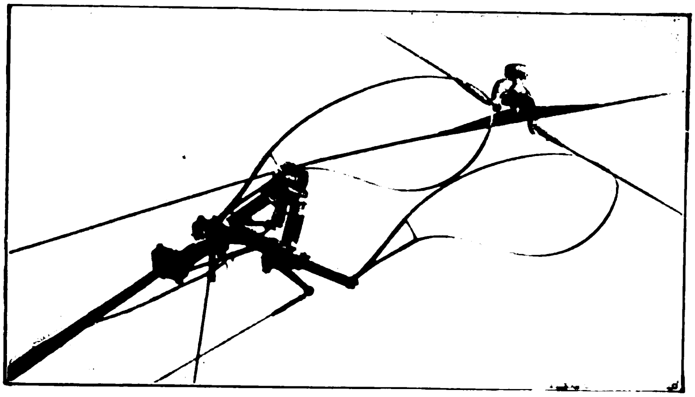

Fig. 15. Trolley Line Insulator Tester.

A simple and efficient overhead trolley equipment tester is now being made by Messrs. Everett, Edgcumbe. Rule 10 of the Board of Trade Regulations states that: "Each separate insulator on the overhead conductors shall be tested not less frequently than once in a month, and any insulator found to be defective

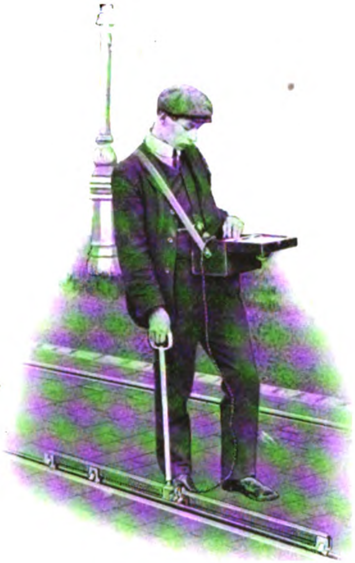

FIG. 17. RAIL BOND TESTER.

shall at once be removed, and an efficient insulator substituted."

The daily insulation test of the entire line from the station obviously affords no indication, owing to the fact that there are two insulators in series at each point. On the other hand, to test each insulator periodically by means of a tower waggon or even a pole and contact is an almost impracticable task, especially on long lines or in crowded streets.

To overcome these difficulties, a system of testing from the car itself has been devised in conjunction with Mr. A. H. Pott, and the form of the apparatus as placed on the market is shown in Fig. 15. It consists of a light aluminium frame which is clamped to the boom, and carries a wooden cross arm pivoted at its centre. This arm carries at each end a light steel spring, which, as the car travels along the route, makes momentary contact with each span wire, as shown in the illustration. The pivoted arm also carries a small fork fitting round the trolley head in such a manner that, however much the latter turns sideways, the cross bar always remains accurately at right angles to the trolley wire. This condition is fulfilled even when the boom swings right out to the side of the car, whilst at the same time there are no projections which can catch in the overhead construction.

During a test the car is usually run at a speed of seven miles per hour, though there is practically no limit in this direction, so that no special trip need be made. A good practice is to send out the apparatus on the first car travelling along each route every day or once a week.

Fig. 16 shows diagrammatically the method of testing the insulator B. If the latter be faulty, a current will flow from the trolley wire through the detector and the contact

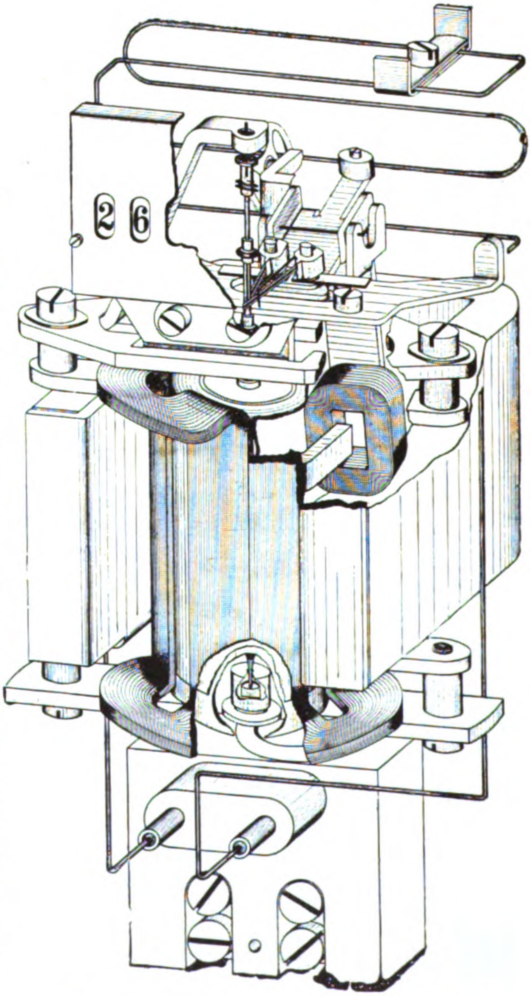

FIG. 18. "EC" TYPE AMPERE-HOUR METER.

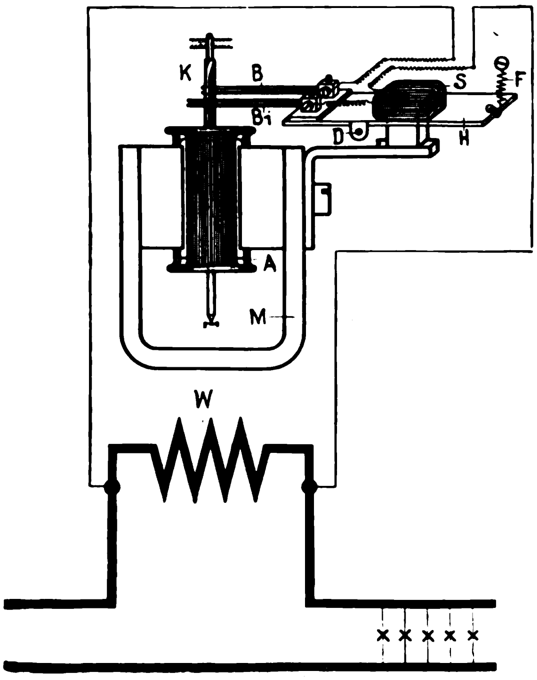

FIG. 19. "EC" METER DIAGRAM OF CONNECTIONS.

spring to the span wire, and thence to earth through the faulty insulator and the pole. For the test of insulator A, the detector is connected between the contact spring and earth, and will show a deflection should the insulator be faulty, and the span wire thereby made alive, as the trolley passes under the faulty insulator. A compact change-over key is fitted, whereby either the A or B insulators can be tested at will without any alteration being required in the connections.

The rail-bond testing set supplied by the same firm is illustrated in Fig. 17, and is of a very simple and compact character. It is made in two forms, viz., with contact-maker for use on tramway systems, and with special contact for testing the live rails of electric railways. It may also be used for testing ordinary rails, which are bonded for signalling returns. With this apparatus it is claimed that the effects of varying contacts are rendered practically negligible.

The following are details of the newest forms of measuring instruments introduced by the Electrical Company, Ltd. Fig. 18 gives a perspective view of the general construction of their continuous-current ampere-hour motor meter with self-adjusting brushes. It is built as a two-wire meter in various sizes for currents ranging from 1.5 to 50amp., and for supply voltages up to 500 volts.

The meter consists of a small motor whose armature revolves in the field of a powerful permanent magnet. The armature windings are carried on a metal bell (Fig. 20), and are connected to a three-part commutator of very small diameter. Two gold brushes bear on the latter and are connected to the ends of a low-resistance shunt which bridges the terminals of the meter. The current of the circuit divides in the meter into two parts: the one flows through the shunt and the other through the armature windings. The interaction of the armature current and the flux of the permanent magnet produces the driving torque proportional to the main current, resulting

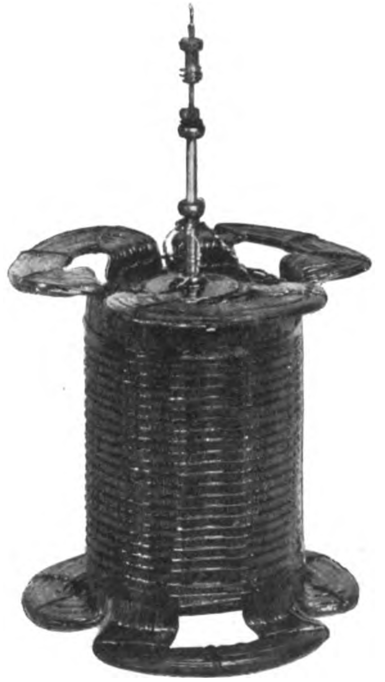

FIG. 20. "EC" METER—ARMATURE.

in the rotation of the armature. As the latter revolves round the stationary iron core between the permanent magnet, eddy currents are induced in the metal bell and produce the retarding torque proportional to the speed. When steady motion results, neglecting friction, the speed is directly proportional to the current. A diagram of connections is shown in Fig. 19. The elements of the meter are mounted on an iron base-plate, which forms one of the special features of this so-called "EC" type of meter. Iron can be used, as the powerful steel magnet of the meter is fixed to the base-plate as its neutral zone. In this way, a sound mechanical construction is obtained, and any distortion due to springing, &c., is entirely prevented.

Another special feature of the "EC" meter is the use of self-adjusting brushes and a twisted commutator, by means of which a higher degree of accuracy is obtained, together with large permanency of calibration. An electromagnet in series with the revolving armature automatically shifts the position of the brushes on the commutator, the segments of which are twisted at their lower ends. A two-fold purpose is served by this combination. In the first place, variable-contact resistance between the commutator and the brushes, typical of all meters of this class, is compensated for. Secondly, the brushes are made to occupy the best position for commutation and the production of maximum torque, *especially at low loads*. The least variation in friction produces a corresponding change in the armature current and an immediate alteration of the position of the brushes due to the action of the electromagnet. The brushes are kept in a constant state of up-and-down motion so long as not only the contact between them and the commutator varies, but also for any variation in the armature current due to alterations of load. Owing to the commutator segments being spirally-shaped at their lower ends, this motion of the brushes also alters the position of commutation and the torque, and the design is such that at the low loads the torque is relatively a maximum.

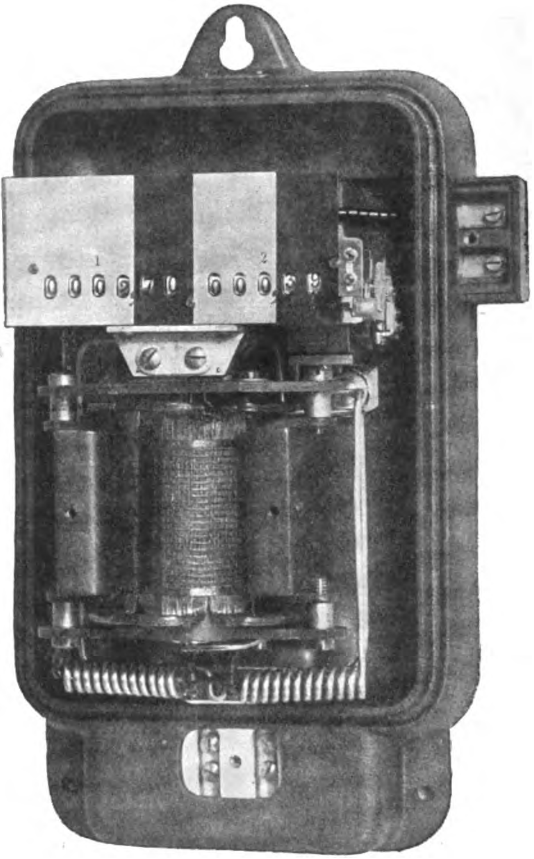

FIG. 21. TWO-RATE METER.

The commutator segments are straight towards the top, so that the position of commutation and the torque at the high loads are not affected by the travel of the brushes. The reason for this is that the meter is practically unaffected by friction on the high loads.

It will be readily seen that shifting the brushes axially in conjunction with the twisted commutator exactly corresponds to shifting the position of the brushes round a commutator with ordinary straight segments for the purpose of increasing or decreasing the load to obtain the most favourable commutation, as with an ordinary motor.

Fig. 22 gives an error curve showing the influence of the twisted commutator; the

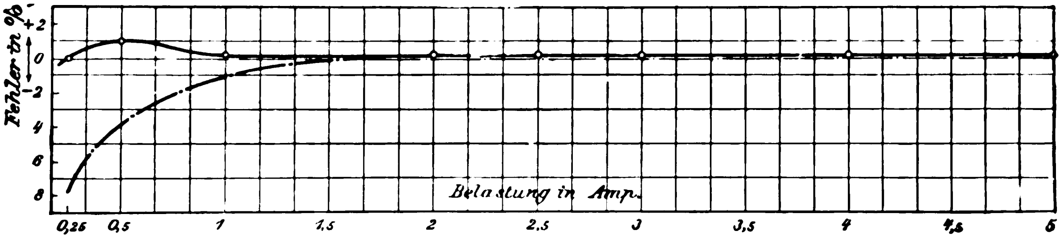

FIG. 22. ERROR CURVE, SHOWING THE INFLUENCE OF TWISTED COMMUTATOR.

dotted curve is that of an ordinary ampere-hour meter with straight commutator segments.

The armature has three former-wound coils mounted on the metal bell, and the windings embrace the poles of the magnets on both sides, so that all the lines of force emanating from one pole to the other are fully utilised.

The meter is calibrated to read either in ampere-hours or in B.O.T. units on a jump cyclometer counter at the supply-pressure indicated on the name-plate. Two covers are provided, one for the meter proper and the other for closing the terminal compartment.

A two-rate meter is illustrated in Fig. 21.

The latest form of single-phase alternating-current watt-hour meter for inductive and non-inductive loads manufactured by the Electrical Company, Ltd., is illustrated in Fig. 23. The meter, type "LJ," is an induction meter on the principle of Ferraris, and is built for pressures up to 230 volts and for various currents ranging from 3amp. to 50amp. for both two and three-wire circuits.

The meter consists of a split-phase induction motor which drives a magnetic brake and a counter. An aluminium disc comprises the rotating element of the meter, whilst the electro-magnetic system producing the driving torque consists of a three-limbed magnet situated above the disc with its yoke arranged below the latter (Fig. 23). The pressure coils are on the outer limbs of the iron magnet, while the main current windings are carried on the shortened middle limb. The two pressure limbs are bridged by a magnetic shunt, and the pressure coils are energised by a current which lags by about 80deg. behind the supply voltage. The angle of phase displacement between the current and pressure fluxes, of exactly 90deg. when the current and pressure are in phase, is obtained by the aid of an iron angle-plate attached to the cast-iron base. The free end of this angle-plate projects into the air-gap between the middle limb and the disc, and carries a short-circuited ring of copper.

By the interaction of the shunt and series fields with the eddies induced in the disc, *i.e.*, the shunt flux with the series eddies, and the series flux with the shunt eddies, the disc is rotated with a driving torque which is proportional to the product of the main current, the supply pressure and the power factor (*i.e.*, $E \times C \times \cos.\phi$, where $E =$ supply pressure, $C =$ current, $\cos.\phi =$ power factor). The work performed by the meter in this manner is dissipated in eddy currents produced in the same aluminium disc by its rotation between the poles of a permanent brake magnet.

The meter is adjusted on low loads by means of a small iron plate attached to the brake magnet. This friction compensator produces a distortion of the field, and can be moved nearer to or farther away from the left-hand limb of the driving magnet. A small piece of bent iron wire carried on the hub of the aluminium disc prevents creeping, *i.e.*, running on the shunt alone, with no current in the main circuit, even with 10 per cent. increase in the supply pressure. At the same time the meter starts with certainty with 1 per cent. of full load.

With regard to the constructional details

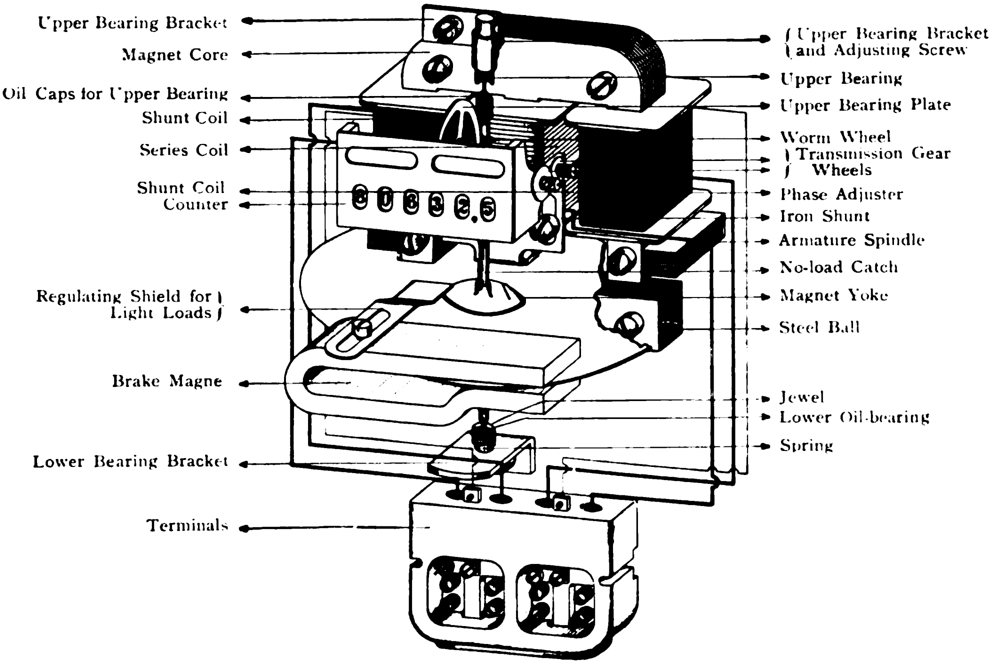

FIG. 23. DIAGRAM OF THE "LJ" TYPE METER, SHOWING CONNECTIONS.

It may be mentioned that the three-limbed magnet as well as the short-circuiting piece and yoke are built up of strips of annealed laminated sheet iron. The sheet aluminium armature disc is mounted on a steel spindle which carries a brass worm through which the counter is driven. The upper end of the spindle carries a small brass sleeve which forms an oil chamber in which is a ring collar bearing held by a cap. The flexibly supported pivot pin projects down through a small opening in the cap into the bore of the collar bearing. The lower bearing contains a steel ball which runs freely on a highly polished sapphire jewel, and is completely immersed in oil. The lower bearing pivot of the spindle is cupped to the shape of the ball.

The brake magnet is adjustably mounted and fastened to the cast-iron base-plate by means of a brass angle-piece. Both the main meter cover and the terminal lid can be independently sealed. The integrating train consists of a jump cyclometer counter with the decimal portion painted red to distinguish the decimal and unit figures. The instrument is calibrated to register direct in B.O.T. units.

The International Conference on "Electrical Units and Standards," held in London in

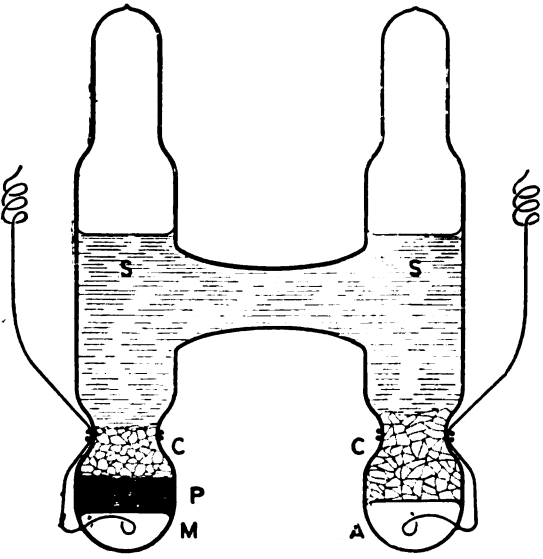

FIG. 24. SECTION OF WESTON NORMAL CELL.

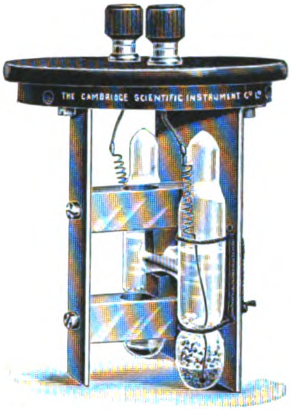

FIG. 25. METHOD OF MOUNTING WESTON NORMAL CELL. BRASS CASE REMOVED.

October, 1908, recommended that the Weston normal cell may be conveniently employed as a standard of electric pressure for the measurement of both E.M.F. and current, in preference to the Clark cell, and there is little doubt that the recommendation will be adopted.

This cell is of the type commonly known as the "Cadmium" cell in this country and the "Weston" cell in the United States. The Conference recommended the name "Weston Normal" cell.

It was early realised that the large temperature coefficient of the Clark cell was a very serious disadvantage in practical use, and experimenters turned their attention to constructing a cell which should combine the advantages of a very small temperature coefficient with the reliability and constancy of the Clark cell. The resulting Weston normal cell has now been most thoroughly tested over several years' time, and is found to comply with these requirements in a very satisfactory manner.

As originally introduced by Weston, it was specified that the cadmium sulphate solution should be saturated at 4deg. C. and no crystals should be inserted in the cell. Later, however, it was found best to have crystals of cadmium sulphate always present so that the solution should be saturated at all temperatures, and the modern cell is thus constructed. The original tube form of cell, specified by the Board of Trade, was greatly improved on by Lord Rayleigh by making it of the "H" form, and this has been further improved on by Mr. F. E. Smith by making a constriction in the side of the vertical tube, so that the top of the layer of crystals is level with the smallest area of the tube, and since the crystals become loosely cemented together, a taper plug is formed by them

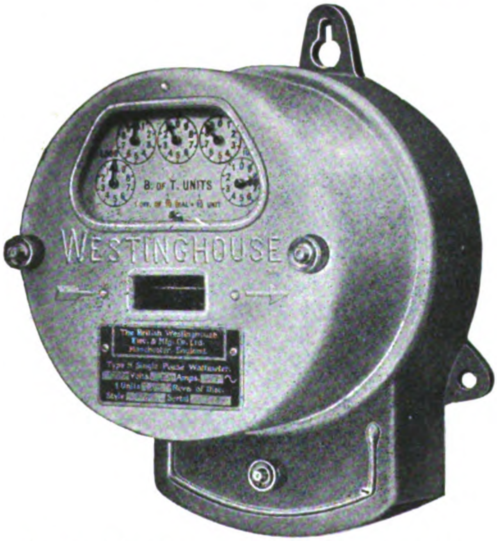

FIG. 26. WESTINGHOUSE TYPE "N" SINGLE-PHASE WATT-HOUR METER.

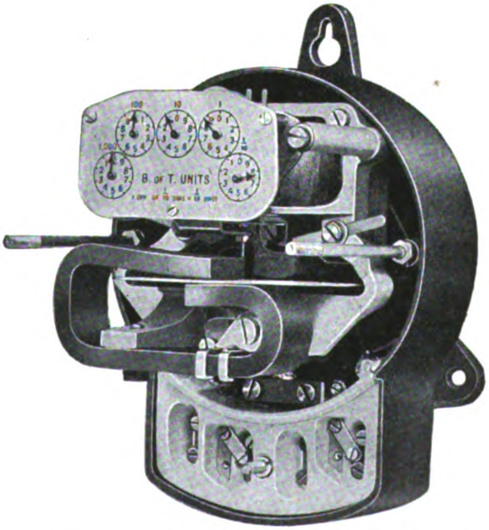

FIG. 27. INTERIOR OF WESTINGHOUSE TYPE "N" SINGLE PHASE METER.

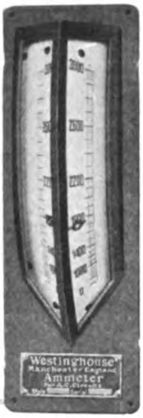

FIG. 28. V-FORM SCALE TYPE "I," AMMETERS AND VOLTMETERS, FOR A.C.

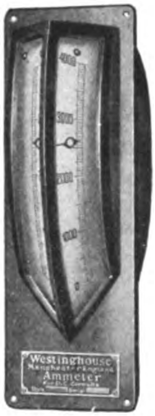

FIG. 29. V-FORM SCALE TYPE "H," AMMETERS AND VOLTMETERS, FOR D.C.

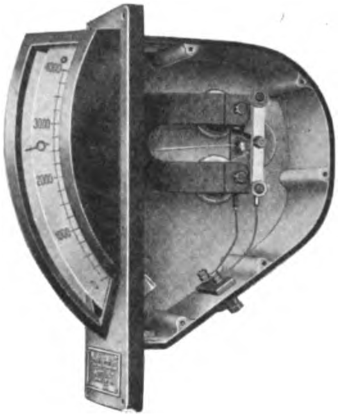

FIG. 30. "N" TYPE, DIRECT-CURRENT INSTRUMENT.

which holds all the contents in their proper places, and makes the cell a much more portable affair, so that it may be sent by post without danger. In fact, cells constructed in this manner by the Cambridge Scientific Instrument Company have been sent to Berlin, Paris, and Washington without suffering any ill-effects from the journey. All the cells constructed by this well-known firm are of the "H" pattern and hermetically sealed. Fig. 24 represents the cell diagrammatically, and Fig. 25 shows the cell as mounted with the brass case removed. It is lashed by silk cord to the framework, which in turn is screwed to an ebonite top. A hole in the ebonite top permits the insertion of a thermometer when desired.

The high state of perfection reached in the construction of this type of cell, and the close agreement obtained between cells constructed by different experimenters, are well illustrated by the fact that the mean e.m.f. of twelve cells sent from the National Bureau of Standards, Washington, U.S.A., to the National Physical Laboratory, was only three microvolts less than the mean of twelve cells constructed at the latter laboratory. Very great care must be taken in obtaining pure and uniform chemicals, particularly in the case of the depolariser, mercurous sulphate, which has been the cause of many of the variations hitherto noticed in standard cells.

The cell has so small a temperature coefficient, that for many measurements it may be entirely ignored. For accurate work, however, it must be applied, and the following formula determined by Wolff is suggested for universal adoption by the International Conference of 1908:

$$E_t = E_{20} - 0.0000406\ (t - 20^\circ) - 0.00000095\ (t - 20^\circ)^2 + 0.00000001\ (t - 20^\circ)^3.$$

This means that for changes in temperature of two or three degrees above or below 20deg. C., the e.m.f. of the cell decreases by between four and five parts in 100,000 per degree rise of temperature, or increases by a like amount per degree fall in temperature. It is advisable to keep the temperature as constant as possible, since it is found that

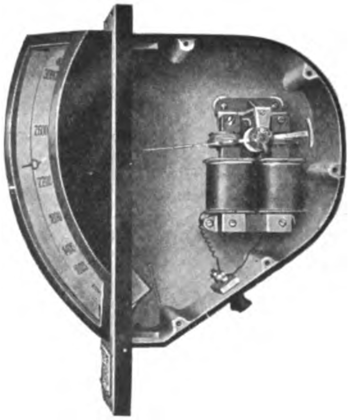

FIG. 31. TYPE "I," ALTERNATING-CURRENT INSTRUMENT.

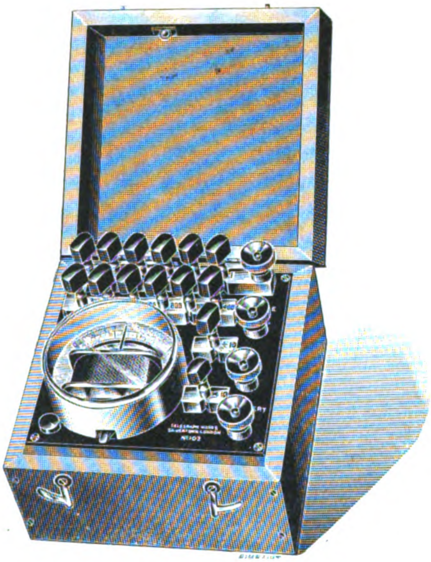

FIG. 32. SILVERTOWN TESTING SET.

there is a lag of e.m.f. with respect to temperature changes. However, when the temperature change is slow and of a few degrees only, the effect is very small.

The resistance of the cell is usually about 900 ohms.

Mr. Smith's investigations into the recuperative power of the Weston normal cell after short-circuiting are interesting. A cell short-circuited for one minute was correct within a ten-thousandth of a volt one minute afterwards, but forty minutes were occupied in its recovery to one part in 100,000. A cell short-circuited for five minutes was one in 1000 low one minute afterwards, but completely recovered in one-and-a-half hours. A cell short-circuited for five days recovered in one day to within two parts in 10,000, and completely recovered in six weeks.

The terminals of the cell are well insulated from the brass case, but if very great insulation is desired the cell should be placed on a slab of paraffin wax. Only very small currents should ever be taken from the cell. Every cell sent out by The Cambridge Company has been tested by the National Physical Laboratory, and the certificate issued is supplied with the cell. It is probable that in the near future these certificates will give the e.m.f. of Weston normal cells in International volts, instead of Board of Trade volts. The Conference (1908) recommended that the cell should be taken, provisionally, as having, at a temperature of 80deg. C. an e.m.f. of 1.0184 International volts.

One of the latest electrical measuring instruments manufactured by the Westinghouse Company is their type N single-phase watt-hour meter, illustrated in Fig. 26. This meter embodies all the latest improvements, and has been specially designed to meet the new conditions necessitated by the introduction of metal-filament lamps. It will start under $\frac{1}{2}$ per cent. of full-load current.

Other special features are—small losses,

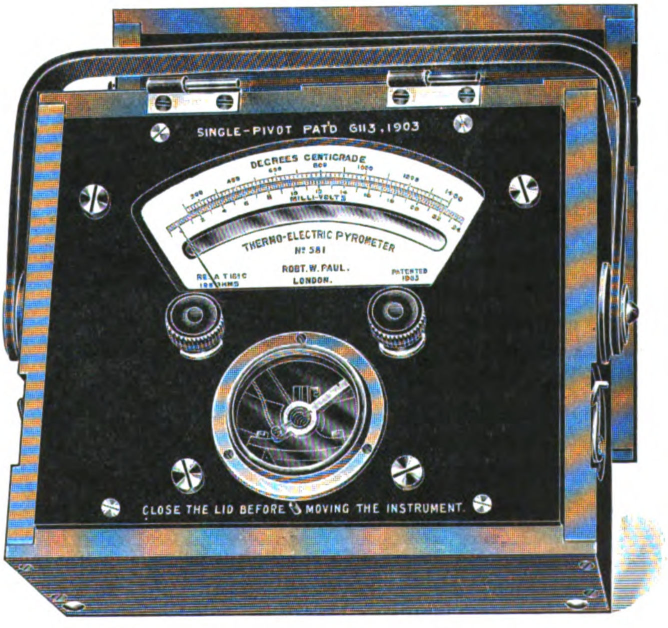
SINGLE-PIVOT PAT'D 6113, 1903
DEGREES CENTIGRADE
MILLI-VOLTS
THERMO-ELECTRIC PYROMETER
No 581
ROBT. W. PAUL.
LONDON.
PATENTED 1903
CLOSE THE LID BEFORE MOVING THE INSTRUMENT.

FIG. 33. SINGLE-PIVOT PYROMETER INDICATOR.

large driving torque, high insulation, unaffected by short circuits, low speed, reduction of friction and wear to the minimum, exceptional accuracy and permanency of calibration ; it conforms on all points to the Engineering Standards Committee's specification for supply meters.

The meter, shown with the cover removed in Fig. 27, is compensated for friction, and shows no tendency to creep. The arrangement used as a compensator consists of two small pieces of stamped brass, forming coils of one turn per layer, and can be moved in position relatively to the iron circuit, thus constituting an exceedingly simple and neat device, which is rigid, and cannot move after adjustment. It is claimed that in this meter the ratio of torque to weight of moving element is very much greater than that obtained by competitors, and further, that this result has been got with the lightest moving element on the market, thus reducing friction and wear, and minimising the chances of the bottom jewel being broken.

In cases where horizontal space on a switchboard panel is limited, the latest patterns of the edgewise ammeters and voltmeters of the Westinghouse Company will be found to be most suitable, since the width of the case of one of these instruments is only 5¼in. The principal feature of these instruments, however, and one not possessed by any other make, is the "V" form of the scale, which design allows readings to be taken from practically any front position. With the usual flat scale, reliable readings can only be taken when viewed directly from the front, whereas it is sometimes necessary that readings be taken from positions considerably to the right or left of the instrument. This can be done easily and accurately with scales of the form shown in Figs. 28 and 29. The scale is long and distinct, enabling readings to be taken from a distance.

In the "H" type, for direct current, illustrated in Figs. 29 and 30, the magnetic system consists of two magnets bolted to a pair of soft-iron pole pieces. Enclosing the outer pole-piece, but not touching it, is a moving coil of fine wire wound on an oblong

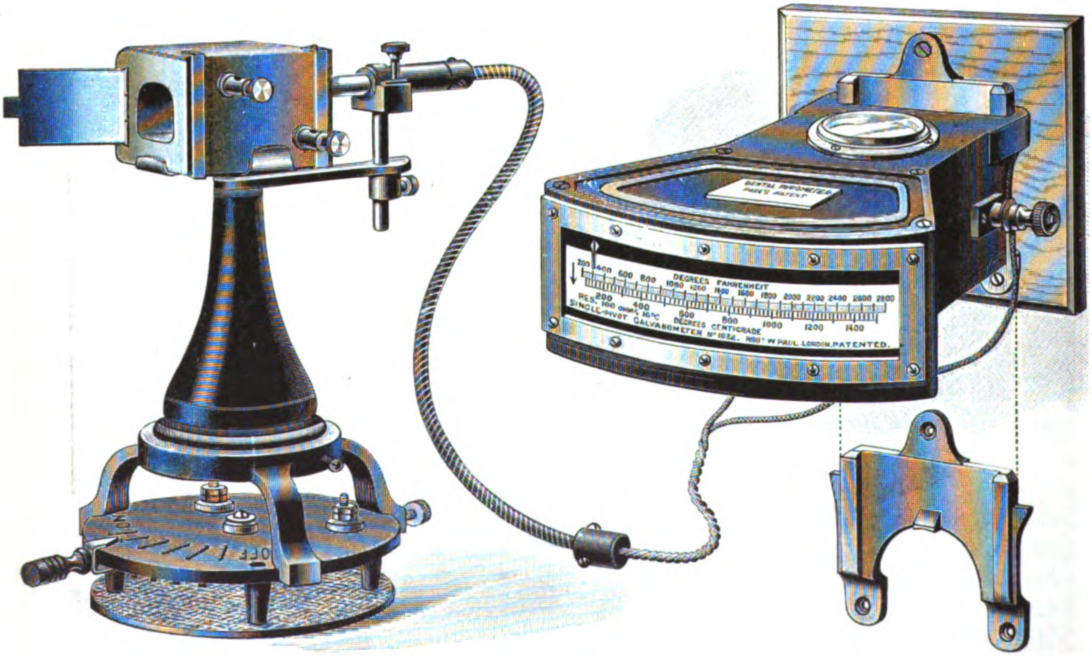

FIG. 34. ELECTRIC MUFFLE FURNACE AND PYROMETER.

aluminium bobbin, and attached to the framework of the movement.

Fig. 28 shows the face, and Fig. 31 the interior, of the "I" type of instrument for alternating current.

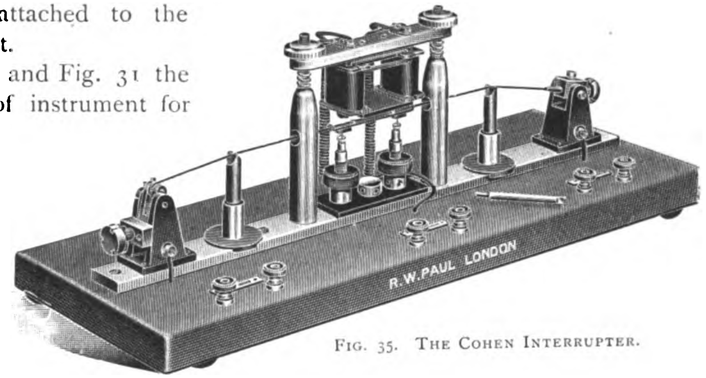

FIG. 35. THE COHEN INTERRUPTER.

The Silvertown portable testing set for measuring conductor resistances of electrical circuits and apparatus is well known. The very latest pattern, No. A1925, manufactured by the India-rubber, Gutta-percha, and Telegraph Works Company, is illustrated in Fig. 32. It consists of a small portable Wheatstone's Bridge, together with a suitable galvanometer, mounted on an ebonite slab and fitted into a polished teak case.

The adjustable resistance contains coils from 1 ohm to 400 ohms, giving a total of 1110 ohms. The ratio coils are so arranged as to require only two plugs, and by their means ratios of ten times, equality, and one-tenth are obtainable. The range which the instrument can measure is therefore from 0.1 ohm to 11,100 ohms, but by means of galvanometer deflections—in the well-known way—suitable resistances may be measured to hundredths of an ohm.

The various parts of this cheap pattern have been so designed as to produce a most compact arrangement; the resistances are not approximate, but are carefully adjusted, and all the plugs have ebonite tops. The galvanometer is similar in construction to those provided in the more expensive sets, and like these is fitted with a spring plunger lifting arrangement, so that the pivot and jewel may not get unduly worn or damaged when the instrument is being carried. A key is provided in the galvanometer circuit (fitted underneath the ebonite slab for protection), which is actuated by the press button seen to the left in the figure. The galvanometer is calibrated, the scale being engraved in unequal divisions, which are proportional to the current strengths, and a mirror to prevent parallax error is provided.

During the last few years great progress has been made in the subject of electrical pyrometry, and up-to-date manufacturers now realise the assistance that the electrician and physicist can give in measuring temperatures which are of vital importance to them. Many improvements have been made by Mr. R. W. Paul in the construction of his latest types of thermo-electric pyrometers and pyrometer indicators. The principle upon which the working of these instruments is based is that electrical pressure is generated by heating the junction between two wires of dissimilar metals, which junction, usually called the hot junction, may be formed by fusing or welding the wires together. The other ends of the wires are connected to terminals suitably encased in a cold-junction box, and thence by insulated wires of any convenient length to a sensitive indicator or milli-voltmeter, which may be placed at a considerable distance from the hot junction and graduated to read directly in degrees of temperature.

The indicators used in the earlier pyrometers had certain disadvantages when used under workshop conditions, mostly due to the necessity of great electrical sensibility in the indicator. Generally this has been obtained by the use of moving-coil voltmeters having the coil suspended by a metallic strip, the accidental breakage of which necessitated the entire adjustment and recalibration of the apparatus, which could usually only be done by the maker. Mr. Paul has overcome this difficulty by the

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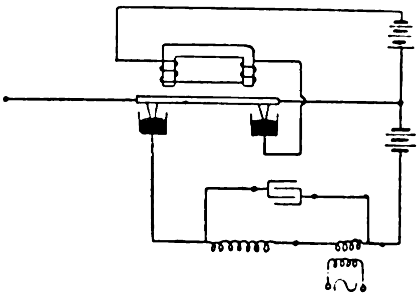


Fig. 36.

employment of his novel and well-known single-pivot method of pivoting the moving-coil of the indicator. The coil has one pivot only placed at its centre, and it is so balanced that the centre of gravity is brought to the point of the pivot, and therefore the instrument does not require levelling, an important advantage when used under factory conditions. Moreover, it is not affected by vibration. When the instrument is lifted for carrying, the coil is automatically raised from the pivot, thus preserving the latter from injury.

An objection to the earlier forms of thermo-electric pyrometers was the non-interchangeability of the thermo-couples, due to the fact that extremely small differences in the metals employed cause large discrepancies in the readings. This objection has been disposed of by an accurate standardisation of the pure platinum and platinum-iridium alloy, which respectively form the two metals used for the junction; also the couples now supplied are not only interchangeable as to e.m.f., but, when mounted in the necessary protecting tube, the resistance of each is brought up to a definite amount; thus the couples and indicators are respectively interchangeable, and the necessity no longer arises for the return of both to the maker, for adjustment to agreement with each other, in the event of either being damaged.

The portable form of Paul's single-pivot pyrometer indicator is illustrated in Fig. 33. The scale, about 5in. in length, is horizontal, and is furnished with a mirror to facilitate accurate reading. The wall type shown in Fig. 34 is arranged for fixing to the wall by means of a plate, to which the instrument may be hooked; duplicates of this plate may be fixed up in different parts of the factory, and the indicator may be moved from one to the other as required. When hooked on to the plate the coil is released automatically and the instrument is then ready for use. The scale is about 5½in. long and is boldly marked for temperatures up to 1400deg. C.

The electric muffle furnace, also shown in Fig. 34, was originally designed for firing dental porcelains, but it may be used for hardening small tools, melting small batches of refractory substances, fusing enamels, and so on. The internal size of the muffle is 2⅜ × 1½ × ⅞in. Current may be taken from any lamp-socket, as the furnaces are wired for voltages from 100 to 120, or from 200 to 250, as required, the consumption being ¼ unit per hour. The regulator shown has five stops for temperature adjustment.

Mr. R. W. Paul has lately placed upon the market a new apparatus for producing small high-frequency currents, and known as Cohen's interrupter, Fig. 35. In most modern methods of measuring small inductances and capacities, such as are used in telephony and wireless telegraphy, a source of interrupted or alternating current is necessary. An electrically-driven vibrating wire has been frequently used to give an interrupted current, and this interrupter can be used in this manner for frequencies from 20 to 500 per second; its utility, however, has been enormously extended by the addition of an extra oscillating circuit containing a set of inductances, a transformer, and an adjustable condenser. An alternating

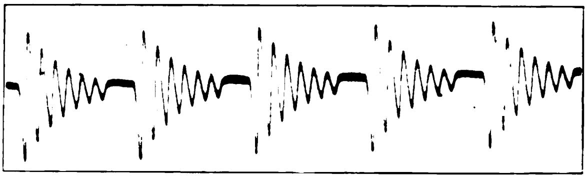


Fig. 37.

current is produced in this circuit, and its frequency may be regulated to any value up to 3000 or more per second by adjustment of the condenser. Further, by using two oscillating circuits continuous waves can be produced, which is a great advantage when absolute measurements have to be made.

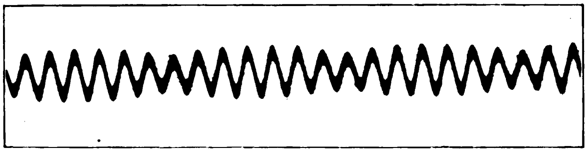


FIG. 39.

The interrupter consists of a steel wire provided with means for altering its effective length and tension, and bearing a soft iron armature; the latter is maintained in vibration by means of a laminated electro-magnet, the circuit through which is made and broken by a platinum contact on the armature, which dips into a mercury cup. A separate contact and mercury cup are placed in the circuit which produces the alternating current, the frequency of which is quite independent of the wire frequency. The mercury cups consist of small glass tubes which are cemented into brass sockets through which the connection is made; each socket is slipped into a carrier provided with a fine vertical adjustment, and can be readily removed for cleaning purposes, while the platinum wire contacts are also readily replaceable.

Owing to the special design of the mercury cups and circuit it is possible to run the wire at full load without any appreciable spark occurring at the mercury contacts. The output can be varied from any small value up to about 3 watts by varying the voltage of the oscillating battery, which for ordinary measurements is about 4 volts. The battery supplying the electro-magnet should give from 25 to 30 volts. By a slight modification of the mercury cups the interrupter may be made to give an output of 50 watts. Several forms of oscillating circuit can be used, of which the two principal may be described as "single action" and "double action" respectively.

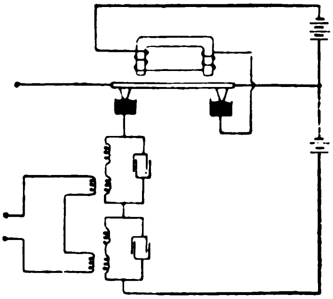


FIG. 38.

Fig. 36 shows the single action circuit, and also the wire driving circuit. The latter requires no explanation. The former consists of a platinum contact and mercury cup, which in the make position connects a battery to a capacity in parallel with an inductance and transformer primary. On the break between the cup and contact, oscillations are set up in the circuit; by this method a series of damped trains of oscillations of any frequency can be produced, the trains following each other with the frequency of the wire vibrations. Fig. 37 shows an example of waves produced by this means; any other frequency would be obtained by merely varying the capacity in circuit. This form of wave is particularly useful for telephonic measurements, and by using the correct frequencies, in conjunction with a barretter or other alternating current measurer, transmission measurements without the aid of the human voice and ear can be rapidly and accurately accomplished.

By using two oscillating circuits, joined up as shown in Fig. 38, and connecting the secondaries to oppose each other, continuous waves can be produced. Fig. 39 shows a wave of 1020 periods per second produced in this manner; such waves can be used for absolute, as opposed to comparative, measurements with a small resulting error.

W. T. CLOUGH.

THE WORLD'S ELECTRIC PROGRESS.

❦

Single-phase Railways.

ALTHOUGH a well-known expert expressed the opinion at the beginning of this year that the use of single-phase current for traction purposes had practically had its day and was indeed no more than a passing fancy, we have still to reckon with this system as one which is receiving the greatest attention from engineers both here and abroad. The completion of the electrified section of the London, Brighton and South Coast Railway has been brought prominently to the public notice by means of a series of trial trips which have been run during the past few weeks and with entire success. At a recent meeting of the East London Railway the question of the electrification of the system was discussed. The lessons of the Metropolitan and District lines were criticised and the decision arrived at was to await the practical results which would soon be available with the running of the London, Brighton and South Coast single-phase railway upon public service.

As indicating the interest which is being taken in the single-phase system of traction on the Continent we are able to give some particulars of the combined Oerlikon-Siemens-Schuckert installation which is about to be put down on the Spiez-Frutigen line in Switzerland. The system here is to be similar to that adopted for the well-known Seebach-Wettingen Railway and which is also at the present moment being installed on the Wiesenthal Railway in Baden. The Spiez-Frutigen line will be operated by a 15,000-volt, single-phase current, 15 periods, the generating plant consisting of steam turbo-alternators. The trolley wire will be of the catenary suspension at a height of some 21ft. above the rails, the collectors of the motor cars and locomotives being of the bow type. The maximum gradient on the Spiez-Frutigen line is 1.55 per cent., but the limiting gradient is found on the continuation of the system on the Loetschberg Railway, where the gradient is 2.7 per cent. The equipment of the tractors will therefore be designed to accommodate this latter gradient. Both motor cars and locomotives are to be used, the former about 65ft. long, having a full seating capacity of 64. They are mounted on two bogies and equipped with four single-phase motors of an aggregate output of 880b.h.p. It is stated that so long as the running of these cars is confined to the Spiez-Frutigen section of the line only two of these motors will be used. The weight of the fully-equipped motor car will be 55 tons and the motors are capable of hauling a train of 160 tons dead weight up the gradient of 2.7 per cent. at a speed of 28 miles an hour. The locomotive intended for the line is to have a total motor capacity of 2000h.p. and will haul trains of 310 tons at a speed of 25 miles an hour against the maximum gradient. In the case of the locomotive each of the two bogies is fitted with a 1000h.p. single-phase motor, which is mechanically coupled to the three axles by means of gearing and rods. Thus the whole of the locomotive wheels are utilised for propulsion.

It is interesting to note that these 1000h.p. motors will be the largest single-phase commutator-type machines ever built, and their operation will consequently be followed with exceptional interest. Both in the case of the motor car and locomotive the line pressure of 15,000 volts is stepped down to a series of lower voltages corresponding to the different operating speeds of the motors. The system is designed for a maximum speed of 43½ miles an hour, and whilst it is intended that the motor cars shall take care of the regular service the locomotives are to be provided primarily for experiments towards deciding whether the electrical system now being put down is entirely suitable for operating the main lines of the railway.

* * *

Electric Eatables.

IN the preparation of food stuffs the electric motor is rapidly taking up an unassailable position. There are few towns today, having public electric supplies, which are without the butcher as a power user. For the driving of mincing and sausage-making machines it does not need any great discussion to reveal the exceptional merits of the cleanly, ever-ready little electric motor for these services. Hitherto small gas engines have held sway, and this reminds us of a young butcher who reported himself as in every way satisfied with the electric motor he used, but who had a grievance against the electrical man, which was that the salesman who sold him the motor indicated how by selling his existing gas engine he could get the electrical plant for next to nothing, whereas his trouble was that now he could not find a customer for the gas engine.

Speaking of meat cutters, it is to be recorded that, at a large sausage factory in Buffalo, what is claimed to be the largest machine of this type is driven electrically by a 20h.p. induction motor connected with the Niagara Falls system. The bowl of this machine is 43in. in diameter and its six knives each have a cutting edge of 18in. The output of this huge machine is 250lb. in five minutes, the particular factory where it is installed having an average output of 25,000lb. of sausages per day. It is interesting to note that this machine used to be driven by a steam engine and that a man was required to keep the engine up to running order, whereas with the motor no engineer is required, the starting and stopping being in the hands of the butcher attendant.

Whilst on this subject of the use of electric motors in preparing food stuffs it is interesting to record that an exceptionally large bakery in Belfast is now being fitted throughout with electric motors by the General Electric Company. The motors are used for an endless variety of purposes—dough mixers, dough turners and dividers, sack hoists, bakehouse plant, fruit machines, and for the several mechanics' and cartwrights' shops, &c. In all some twenty motors are being put down. An installation of the General Electric Company which is attracting quite a considerable degree of attention is that of the Co-operative Wholesale Society's Flour Mills in Silvertown, which are equipped throughout with squirrel-cage induction-type machines. In this case upwards of fifty motors are in constant use. This plant is exceptionally interesting owing to the proved success of the induction motor in a service for which some doubt as to its suitability has been expressed.

* * *

Who Invented the Tungsten Lamp?

OUR American cousins, true to their traditions, have lately entered the lists with a claim for one of their citizens as the original discoverer and inventor of the tungsten lamp. This credit is claimed by them for Mr. T. D. Bottone, an electro-chemist and inventor. It is said that he discovered the tungsten lamp when barely eighteen years of age in the year 1887, during the time he was associated with a lamp company in Harrison, N.J. His first patent is said to have been filed in September of that year, and subsequent patents appeared from time to time until August, 1889. Mr. Bottone was associated with a clergyman of considerable means, which enabled the inventor to carry his studies to something like finality.

* * *

Improved Harrison Photometer.

THIS well-known instrument, which is manufactured by Messrs. Elliott Brothers, has recently been considerably improved by the addition of a simple attachment that enables the horizontal illumination from all sources to be measured.

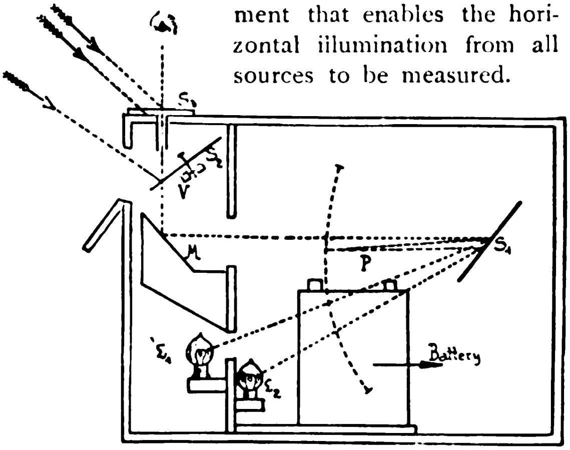


FIG. 1. THE HARRISON UNIVERSAL PHOTOMETER

S_1—Adjustable screen attached to pointer.
P—Pointer on outside of case.
S_2—Revolving sector screen for general illumination.
S_3—Screen for horizontal illumination.
M—Reflecting mirror.
$L_1 L_2$—Standard lamps.

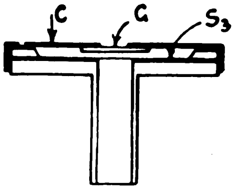
The photometer is intended for the measurement of illumination on a screen making an angle of 45deg. with the vertical, and for the measurement of the candle-power of various sources of light. The instrument is provided with a flicker disc rotated by a blast of air under the control of the operator. By fixing the flicker disc to half cover the field of view of the eye-piece the instrument may be used as a direct comparison photometer, the illumination of the source of light being compared directly with that of the adjustable screen inside the instrument illuminated by a small standard lamp connected to a self-contained accumulator battery.

The recent addition to the instrument consists of a horizontal screen which is covered by a cap when the flicker disc is used. This cap has a hole through the centre, and forms the eye-piece of the instrument. When the cap is removed the horizontal screen is exposed, and by fixing the flicker disc out of the field of view of the eyepiece, by means of a small milled headed screw, the photometer can be used to measure horizontal illumination by direct comparison. The outline drawing of the instrument, Fig. 1, together with the enlarged view of the eye-piece, Fig. 2, will make the construction quite clear.

The illumination to be measured is in all cases read off directly on the scale by means of the pointer shown, which is fixed to the adjustable screen, by moving which balance is obtained between the illumination of the source of light under test and that due to one of the small standard lamps inside the instrument.

From the foregoing it will be seen that the following tests can be made with the instrument :—

1. Candle - power by means of flicker disc.
2. Candle - power by direct comparison method.
3. Illumination on screen at an angle of 45deg. by flicker disc.
4. Illumination on screen at an angle of 45deg. by direct comparison method.
5. Horizontal illumination by direct comparison.



Enlarged view of eye-piece

FIG. 2.

C—Cover cap.
G—Glass in eye-piece.
S_3—Screen for horizontal illumination.

The original features of the instrument have all been retained and the new model is just as simple to manipulate as the older pattern. The advantages of the instrument consist of :—

Light weight and portability; wide range due to use of two standard lamps of different candle powers; permanent connection between battery and rest of circuit, which need never be disconnected for charging purposes, &c.; battery, standard lamps and flicker disc may be readily removed from instrument for inspection, without disconnecting or altering any adjustments; easy and accurate manipulation due to arrangement of pointer screen and flicker disc. We may mention that the addition of the new horizontal attachment does not increase the cost of the instrument owing to its simple construction and method of manufacture.

The Electric Arc and Gaseous Reactions.

An improved method of carrying out gas reaction processes, by the use of high-tension alternating arcs, is described in the "Zeitschrift für Elektro Chemie." Such a process is, for instance, the fixation of atmospheric nitrogen, for which purpose large plants are being laid down in Germany. Hitherto the series of arcs, which are of high power, were energized by an alternator, the stator coils of which were connected in series. A variation of resistance in one arc affected the whole circuit; if more than one arc varied, the effects became cumulative, and heavy fluctuations of energy were experienced. making the plant difficult to control and uneconomical in operation. The starting up of the plant was attended with special difficulty. The new arrangement provides as many coils in the stator of the alternator as there are arcs to be energized, and each coil is connected independently to one arc, so that any fluctuations of energy at the arc are confined to its particular coil and have no effect on the other circuits.

The arrangement produces economy both in first cost and in the cost of energy.

❧

Controllers and Starters.

The design of electrical motor controlling and starting apparatus calls for much expert knowledge and wide experience. So much is this the case that many firms engage almost solely in this branch of manufacture. The chief features of the controllers made by the Electric and Ordnance Accessories Company, Ltd., are the fireproof and non-hygroscopic nature of the materials employed, enabling them to be used with satisfactory results even in damp places. The contact fingers are placed in separate fire-proof chambers, and are of stout hard drawn copper. Between the fingers and the brass carriers is a phosphor-bronze spring, and the current is shunted across this by means of a copper laminated contact, thus effectively preventing heating of the spring. All direct current controllers are fitted with powerful magnetic blow-out coils, which are in series with the circuit control. The blow-out arm can be swung back, giving easy access to the fingers, &c. In the vertical type controllers the operation of the drum is made easy by the use of a ball-thrust bearing at the base. In addition a pawl and disc attachment produces a snap action which renders it impossible for the controller arm to be left in any intermediate position between the contacts. Large numbers of these controllers have been supplied to the Admiralty for use in dockyards and on battleships, &c., and in addition they have been largely taken up by leading crane-makers.

The motor starters of this firm are manufactured in the usual types, viz., open, enclosed, water-tight and gas-tight types, and can be fitted with either no-volt release or no-volt and overload releases. The starters are designed for the purpose of starting only, and are rated to do so against an overload of 50 per cent., the test before shipping being made on this basis. Starters for motors above 10h.p. are fitted with renewable contacts, which can be replaced without interfering with the connections. The resistances fitted with these starters are designed to give equal increments of current between each stop, thus starting up the motor gradually and without sparking; also care has been taken to keep well within the sparking voltage between successive studs, this being an important feature in starters for voltages of higher than 250. The resistance units are of special material and unbreakable, and will not deteriorate through long and frequent use. They are incombustible and do not smoke or smell when in use. The resistances are of the matt type, constructed of material which is impervious to moisture, and which are in detachable units.

A starter of great interest is the autograd motor starter, Fig. 1, as manufactured by this firm. This has been specially introduced for use in industrial situations where the plant is left in charge of unskilled and incompetent employees. The only motion needed is to push the handle into the starting position; the automatic gradual starter does the rest. This is achieved by means of a small pot magnet on the starting lever, which, when moved over, attaches itself to an armature on the contact arm, and a flat steel spring behind the slate draws the contact arm over the contact plates. The speed of this arm is regulated by a dashpot, and the motor is thus prevented from starting up too rapidly. An overload device is provided, and operates immediately an overload or short-circuit takes place. It also operates with equal efficiency when the switch is in the full-on position, and if an overload occurs during the act of switching on, the pot magnet is at once de-energised, causing the starting lever to fly back to the original position, while the contact arm moves back to the starting position. The controlling action of the dashpot renders it impossible to accelerate the switch sufficiently to cause damage to the motor, and the whole starting device ensures the motor-starter being entirely fool-proof.

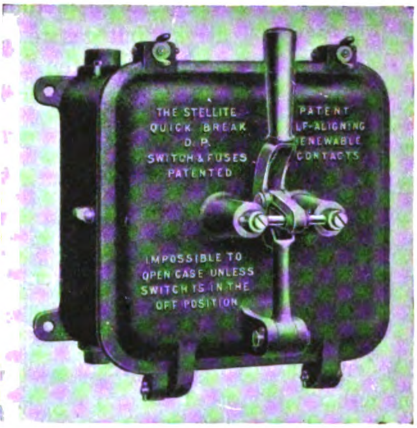


FIG. 2. ENCLOSED D.P. QUICK BREAK SWITCH AND FUSES.

For use in conjunction with starters and other general house-lighting installations, the enclosed switch combined with cartridge-type fuses, shown in Fig. 2, is in good demand; this dispenses in many cases with the objectionable practice of having the main switch and fuses distinct. The device is enclosed in a substantial cast-iron case, perfectly water-tight, gas-tight, and fireproof; it is, therefore, suitable for use in any position. The switch is of the lever type, and makes absolutely quick make and break. The switch lever is not solid with the make and break mechanism, but is quite free, and operates in a loose link, the quick make and break, therefore, being altogether independent of any retarding effect caused by the slow movement of the person opening or closing the switch. This apparatus is suitable for lighting and power circuits up to 600 volts.

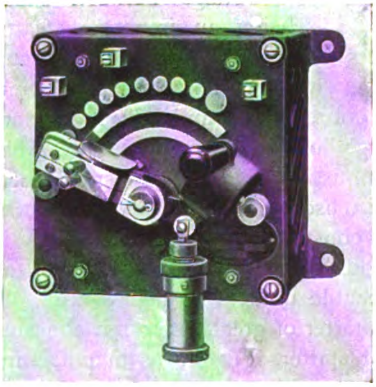


FIG. 1. "AUTOGRAD" MOTOR STARTER.

The Electrical Equipment of Collieries.

THE great and rapid strides which have been made in the utilization of electric power in and about collieries and mines during recent years has naturally resulted in an ever-increasing demand for books which deal specifically with this branch of electrical practice. Many and diverse have been the publications of this character published even during the past year; some compiled by mining engineers, others by electrical engineers – books complete in themselves to be had for a few shillings, and multivolume treatises to be had on the easy-payment system. It is to be noted, too, that these same new books are as diverse in character as in form of publication, and some few entirely miss their object, being neither of electrical nor of mining value. The latest arrival is a book published at half-a-guinea by Messrs. Scott, Greenwood, and Son, entitled "The Electrical Equipment of Collieries," and upon which Mr. W. Galloway Duncan, electrical engineer, has collaborated with Mr. David Penman, colliery manager. The result of this promising alliance is good; there is a real practical and commercial value attaching to the work which will be duly appreciated by engineers. We do not know that it is really necessary in a book of this description to open the subject with surmises as to the nature of electricity, introducing the legend of amber rubbing and passing on to the principles of cells, porous pots, magnetic polarity, &c. In the book under notice, however, there is little cause for complaint on this score, for only a dozen or so pages of such elementary matter require to be "skipped" and the reader is at once amongst practical, modern, electric power machines. The descriptions and illustrations of electric plants and the facts relating thereto are concise and valuable in that the authors are evidently keenly alive to the requirements of the colliery engineer. Of exceptional value are the chapters which deal with the transmission and distribution of power and with the initial outlay and working cost of electrical installations. The section of the book which gives actual money values of various machines and plant introduces also figures of comparison, such as, for instance, motor versus steam driving; gas, steam-engine, and steam-turbine units; transmission losses and plant efficiencies. The figures quoted may be accepted as reliable, and in this feature alone the book will prove to be the one long sought for by very many colliery men, and which incidentally is likely to be the means of saving the electrical plant manufacturer some considerable time, labour, and expense; for the average colliery engineer, contemplating an electrical venture, usually gets some half-dozen or more of the leading electrical firms to tell him what he needs, quote to those needs, modify the specification and requote, and so on—all very expensive work for which no charge can be made, and which not infrequently ends in the postponement of the projected venture *sine die.* Every electrical firm has stacks of correspondence, estimate sheets, and drawings marked "dead" or "in abeyance," as a sorry monument to the lack of such information in colliery circles as this book contains.

❧

Electric Fertiliser.

THE many experiments that have been made during the past few years in this country and abroad towards the fixation of atmospheric nitrogen have resulted in the consummation of providing products for the commercial market. The Birkeland-Eyde process is in full commercial operation in Norway, and its product in the shape of nitrate of lime is now on the British market for the benefit of agriculturists. Small quantities of this material were certainly to be obtained last year, but now it is available in bulk. The new fertiliser is supplied as a fine powder which is perfectly soluble in water, is without odour, and is therefore ideal for treating the land. It has already, in the one or two tests that have been made, demonstrated great possibilities. For example, Prof. John Percival, Director of the Agricultural Department, University College, Reading, publishes the results of some tests which he made with mangold growing. The respective yields per acre with fertiliser at the rate of 1½cwt. per acre were, with nitrate of lime 37 tons, nitrate of soda 36¼ tons, calcium cyanamide 35 tons, sulphate of ammonia 32½ tons, and with no nitrogenous manures 27⅝ tons. Another test carried out by Mr. Patrick Wright, of the West of Scotland Agricultural College, showed that with oats the addition of nitrate of lime in place of nitrate of soda, with other phosphates and potash, gave an increase in grain of some 14 per cent. and 5 per cent. in straw. It is little wonder that in view of these figures, which certainly support the claims of the makers, the new fertiliser is attracting widespread interest in agricultural circles.

❧

Dexine.

Owing to the increasing demand for their well-known specialities in the district, the Dexine Patent Packing and Rubber Company, Ltd., announce that they have found it expedient to open a new warehouse and stores at 74, South Castle Street, Liverpool. The new premises carry a large stock of jointing rings, pump buckets, manhole rings, and the numerous packing and jointing specialities listed by the firm. The Liverpool branch is under the management of Mr. Charles Gibson. As a substitute for rubber, and in many cases as an improvement upon that always expensive material, for mechanical purposes the Dexine products have become firmly established and are in ever-increasing demand. To those connected with the operation of power plants and who are not yet familiar with Dexine it will be sufficient to indicate that it is an elastic and stable material which will withstand continuously temperatures up to 350deg. F., and in the form of pump buckets is guaranteed for working pressures up to 500lb. per square inch. For this particular service, *i.e.*, for pump buckets, its superiority to leather is self-evident, the specific claims of the makers being that it will not soften or change its nature in steam, hot, or cold water, and that it introduces less running friction or wear-and-tear than any other form of bucket. The illustration, Fig. 1, shows the method of attaching Dexine buckets to an ordinary pump piston.

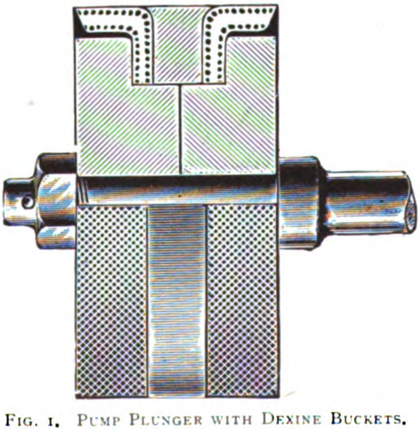


Fig. 1. Pump Plunger with Dexine Buckets.

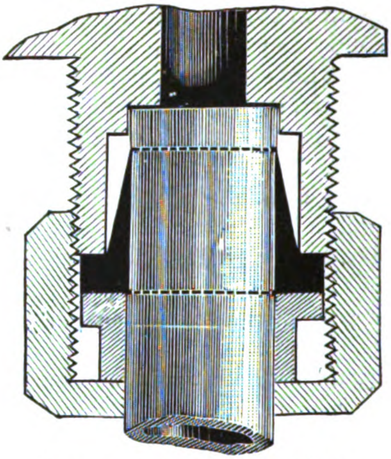


Fig. 2. Dexine Gauge Glass Ring.

For steam main packing Dexine can be obtained either in sheets or rings; it is claimed to be perfectly safe for use with super-heated steam and for pressures of 300lb. per square inch. Smaller specialities are the inadhesive packing rings supplied for stop valves, throttle valves, sluice, feed, scum, blow-off valves, &c. Complete valves of all shapes and sizes and of both the dish and flap types are also made and guaranteed to be in every respect superior to rubber. Hard valves are made for straight lifts, and in practice these have been used for many months under a 270ft. head without the grid mark being scarcely perceptible on the valve, and giving practically noiseless operation.

The second illustration, Fig. 2, shows the form and method of fitting Dexine gauge glass rings and is self-explanatory. It is of particular interest to know that Dexine can also be used as a substitute for ebonite and hard fibre for insulation and electrical accessory purposes; it can be moulded into practically any design, can be readily tooled, and will make a fine thread. In some of its forms it is widely used for electrical gloves, trolley insulators, sleeves, bobbins, switch handles, insulating ground mats, sheets, &c. Altogether, as will be gathered, Dexine is proving itself to be one of the most important and valuable of materials at the disposal of engineers.

The Supremacy of the Induction Motor.

THIS is essentially the age of the polyphase induction motor. Whatever may have been the reason for hesitation in putting down alternate-current industrial plants—whether it was the reputed complexity of the three-wire alterate-current network, the inability of the motors to take up heavy starting loads, or its lack of fine and wide speed variation—all these seem to have been set aside once and for all. The greatly superior merits of the induction motor in the form of great reliability, simplicity, minimum wear-and-tear and maintenance charges, freedom from fire risks, and independence of adverse surroundings and skilled attendance, have become definitely established to the point of seeing the gradual extinction of direct-current motors in workshop, mill, factory and mining practice.

In the case of wood-working shops, flour mills and collieries, heavy power motors are frequently required to start up under full load and always need to be so enclosed or designed as to render the firing of the surroundings by electric spark an impossibility. The enormous expense of large-sized totally-enclosed direct-current machines, or the expense and frequent impracticability of housing direct-current motors in cubicles connected by flues with the outer air, as required by fire-office regulations, has meant the exclusion of direct-current plant and the perfecting of induction motors. Squirrel-cage induction motors never require any more enclosing than can be got by the end gratings, which prevent accidental mechanical injury to the machine, but which allow of a full natural ventilation of the windings. The auto-transformers or starting and controlling gear are arranged to work with all live parts entirely immersed in heavy oil—indeed, no part of the metallic electrical circuit need be exposed to the open air; the cables to and from the starter pass direct into the oil tank and are insulated throughout their entire length right into the stator windings of the motor. Soldered connections are made to the motor leads, and the joints perfectly insulated as for a simple cable joint.

The "G.B." Surface Contact System.

AT a recent meeting of the Institution of Electrical Engineers, a paper was read by Mr. Stanley Clegg, manager of the Lincoln Corporation Tramways, giving his experience of the G.B. surface contact system, which has been running successfully for three years.

The paper and subsequent discussion are of special interest in view of the difficulties experienced by the L.C.C. with the track in the Mile End Road, London.

Although Mr. Clegg compared the G.B. system with the common overhead trolley installation, it really competes with, and is more comparable to, the conduit system. In both systems the transmission is underground, and the visible portions, namely, the contact studs in the one case, and the slot rail in the other, are flush with the road surface; hence, unlike the trolley system, they do not affect natural or architectural beauties of the locality, nor do they offer any obstruction to the traffic—a fact of great importance in busy cities. According to Mr. Clegg, the G.B. system only costs 10 per cent. more than the overhead transmission, whereas the conduit costs about double, without taking into account the special work which may be necessary, owing to the depth of the conduit, its comparative inflexibility and drainage requirements.

The G.B. underground transmission is completely sealed, so that drainage need not be considered; further, the transmission is continuous at points and crossings, whereas the conductor rail in the conduit has to be interrupted at such places.

As regards the safety of the public, the conduit system stands first. With the trolley system there is always the remote danger of the wire breaking and the live conductor falling amongst the street traffic.. The danger with the G.B. system, and this also has possibly been exaggerated, lies in the chance of a stud remaining alive after the car has passed over it; but every car has a trailing brush which indicates the existence of a live stud, and measures can be taken to prevent accident arising therefrom. It is significant that in the whole three years of working at Lincoln there has been no accident.

Mr. Clegg compares the G.B. system with the trolley system, to the advantage of the former; but it will be a long time, if ever, before the well-proved trolley line gives way to any extent to the surface contact.

❧

Ferro-alloys in Castings.

For years advantage has been taken of the fact that the nature of steels may be rendered more suitable for special work by the admixture of metals such as manganese, silicon, aluminium, nickel, phosphorus, titanium, vanadium, chromium, &c.—different metals affecting the hardness, ductility, toughness, and other qualities of the steel.

Very naturally it was assumed that a similar treatment of ordinary varieties of foundry iron would lead to equally beneficial results, and numerous experiments have been made to that end. The chief difficulty encountered was the high melting-point of some of these metals. According to the "Journal du Four Electrique," this has been overcome by means of the electric furnace, which enables the special metals to be combined with iron in small quantities, the resulting alloys having a melting-point sufficiently low to permit of their being properly mixed in the cupola with the ordinary brands of foundry pig.

❧

Graphite in Boilers.

Writing to one of our American contemporaries, a correspondent gives a hint which might well prove of considerable advantage to many who have charge of boiler plants. He says that, being in charge of some six 250h.p. water-tube boilers, it was necessary to clean them out once every six weeks, and he got into the way of putting about 2lb. of flake graphite in each drum of the boilers after cleaning. He found that by this means the scale did not adhere to the boiler surfaces, and in the tubes came away very readily. Examination showed that a film of graphite formed between the scale and the metal, thus preventing its close adhesion.

❧

Wireless Telegraphy on Ships.

The collision which occurred recently between the two passenger steamships, the "Republic" and the "Florida," off the American coast was happily unattended by loss of life, and it is gratifying to note that this fortunate escape was undoubtedly due to the two ships in question having each a Marconi wireless-telegraph system as a part of their equipment. Immediately following the reports of the vital part which the Marconi system had played in this emergency, the first steps were taken towards rendering it compulsory for all passenger boats to be fitted with a wireless-telegraph station as an indispensable and essential adjunct. Quite a remarkable feature of this episode, from the technical point of view, is that which reveals what has hitherto been considered the weak point of wireless telegraphy as an undoubted advantage for such emergencies as these. The very lack of definite "tuning" meant that when signals were transmitted broadcast from the two distressed vessels they were received and read at several places in the neighbourhood with the result that immediate help was forthcoming from many quarters.

* * *

McGeoch Specialities.

SEVERAL entirely new designs in the way of switchgear and electrical accessories have recently been put on the market by William McGeoch & Co., Ltd. These include a line of three-phase oil-immersed switches and also iron-clad switchgear. The illustrations Figs. 1 and 2 show two views of a new crane knock-off switch, which is specially designed for use with overhead electric travelling cranes, to automatically prevent the crane over-running a given point. It is also very suitable for use as a similar safety device with lifts and hoists. The switch parts are assembled on a cast-iron frame, enclosed with a perforated sheet-iron cover. The switch catch is fitted with a special spring arrangement, so that after being knocked-off, the switch automatically resets itself to its original position.

Other specialities include a new type of electric hand lamp, constructed of insulating material in accordance with the Home Office suggestions, and so arranged that no shock can possibly be obtained by anyone handling the lamp; a special feature of this novelty is the provision of a cord grip above the lampholder plate inside the lamp, which prevents the leading-in cable being accidentally withdrawn.

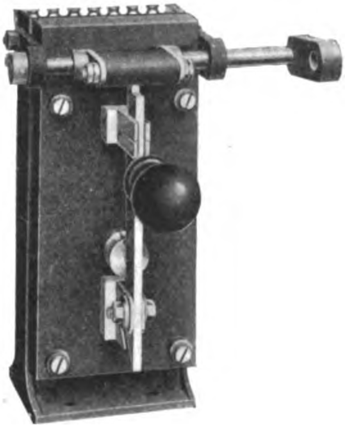


FIG. 1. CRANE KNOCK-OFF SWITCH, CLOSED.

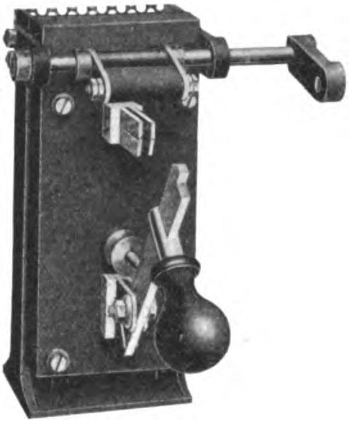


FIG. 2. CRANE KNOCK-OFF SWITCH, OPEN.

* * *

Wireless Telephony.

PROFESSOR QUIRINO MAJORANA, of Rome, has, according to the "Electrician," recently carried out successful experiments in wireless telephony between various points on the Italian coast and a warship which was stationed at different distances out at sea. It is generally known that undamped oscillations are necessary for wireless telephony, and the Professor at first used an apparatus of his own invention, but in his latest experiments he uses the Poulsen arc for generating these oscillations. Owing to the high voltages and comparatively heavy currents required in wireless telephony, the ordinary granular microphone, as used on land lines, is unsuitable. Prof. Majorana therefore designed a liquid microphone, which has been very successful both for wireless and ordinary telephone work. This microphone consists essentially of a small glass tube, through an opening in which a stream of slightly acidulated water flows under a known pressure. The tube is fixed to, and therefore vibrates with, the membrane of the microphone. The jet of water falls between two platinum electrodes, thus connecting them electrically. When the membrane vibrates in response to the sound waves, the movement of the tube causes constrictions in the jet, and thus varies the resistance between the platinum electrodes. The sending apparatus consists of a copper-carbon arc enclosed in a hydrogen atmosphere (Poulsen), with an oscillatory circuit, made up of a capacity and the primary of a Tesla transformer; the secondary of the latter is connected at one end to the antennæ, and the other end is led through the microphone to earth. The sound waves, acting on the microphone, modify the resistance of the secondary circuit and therefore also affect the oscillations transmitted to the antennæ.

The receiving apparatus consists of a similar oscillatory circuit, with the microphone omitted in the secondary; in the primary, a thermo-electric detector is placed in series with the telephone receiver, and these two are connected across the terminals of the condenser. The detector, consisting of a thermo couple composed of two metals in close contact, varies in temperature according to the oscillatory current in the primary circuit, and produces corresponding variations of current in the receiver. These variations are thus reproduced as sound waves in the ordinary way.

The two sets of apparatus must be very closely tuned, otherwise messages will not be intelligible. Perfect communication has been maintained over a distance of 187 miles—the speaker's voice was received in strong and clear tones, recognisable even at some distance from the receiver.

⁂

"Aegma" Metallic-Filament Lamps.

WE have been asked by the Electrical Company, Ltd., to advise readers that the "Aegma" metallic-filament lamps can now be obtained at the following prices:—50c.p., 200 to 250 volts, pear shape 4s. 9d. each; 50c.p., 200 to 250 volts, round bulb, 5s. 3d. each; 100c.p., 200 to 250, volts, round bulb, 8s. each; subject to liberal trade terms. A full price sheet is about to be published dealing with these lamps, and copies will doubtless be sent on application to anyone interested. The particular trend of further improvements in the metallic-filament lamps is all towards increasing the mechanical strength of the filament. This research work has been accompanied by considerable success, and purchasers need have no fear that the newest types of lamps are above reproach in this respect.

⁂

"Cellit"

"CELLIT" is a new substance recently introduced by a German chemist. "Le Gaz" states that chemically it is similar to celluloid, and combines all the advantages of the latter without its dangerous inflammability. Some forms of "Cellit" will not burn at all, while others only burn very slowly; it can be made hard or soft, rigid or pliable. It is said to be an excellent insulator, and lends itself readily to the moulding of the more intricate forms which are difficult to produce successfully in earthenware or porcelain.

⁂

Trade Items.

MESSRS. PRITCHETTS & GOLD inform us that a fire occurred at their works at Feltham in the early hours of the 21st ult. Considerable damage has been done, but steps are being taken to restore matters to a normal condition as soon as possible, although some inconvenience and slight delay in deliveries will be unavoidable.

We learn that owing to the expansion of the Linolite Company's business, it has been found necessary to provide larger works for the manufacture of "Tubolite." The Company has therefore acquired the freehold of some three-quarters of an acre of land at South Acton, and the existing buildings have been rearranged and adapted to the firm's requirements so as to ensure the comfort of the workman, and afford adequate provision for dealing with the increasing demand for this well-known speciality.

The
Electrical Magazine.

VOL. XI. NO. 3. MARCH 15th, 1909.

A SERIES OF COMPARISONS BETWEEN ELECTRICITY AND GAS.

◆

2.—In Domestic Heating and Cooking Service.

(Continued.)

WITH so many different applications and so many different classes of apparatus available, it is very difficult to estimate the cost of heating systems using coal, gas, electrical energy, &c., while keeping the conditions, capacity of heaters compared, and so on sufficiently identical to make valid any deductions based on the comparison. Our object is to collect such data that the difference in cost of the various systems is due solely to the various types of energy employed and not to differences in the "finish" of the apparatus, &c. Some attempt has been made in Tables XI. and XIII. to estimate the total annual cost of various systems for cooking and room warming respectively. The difficulty in the compilation of these tables lies in the practical impossibility of accurately allowing for labour and depreciation costs and for those "indirect" charges referred to later.

Tables IV. to XV., however, are the average results of much data collected and analysed by the author, and are believed to be very representative. Two rows are provided in Table IV. for every system. In these rows the cost of ordinary plain apparatus and of more or less decorated styles are recorded respectively. It is, of course, impossible to take definite standards of decoration throughout, but the prices given show the relative increases of cost due to the decoration of the various apparatus. The degree of decoration is represented where possible by the letters D, DD, &c. (much as the hardness of a pencil is denoted by H, HH, HB, &c.). No definite meaning can be attached to these letters, which are only indicative in their nature. D* is taken to mean the most highly finished product available without going into absurd extravagance.

It will be seen that, as in lighting service, electricity permits the most artistic effects with a minimum expenditure of outlay, and, moreover, the increased decoration does not result in a great increase of weight as is the case with many patent stoves. The electrical equipment is ridiculously light when compared with many of the coal grates mentioned (see Table III.). The latter, if of the slow combustion stove type, weigh anything from 1cwt. to 1 ton when empty, and correspondingly more when charged.

Referring to Tables IV. to XIV., the following conclusions may be drawn from them, though the general scheme of the tables has been so devised as to make them as readable and self-explanatory as possible. The building economies referred to in Table IV. were obtained as mentioned later (see page 122). The remaining costs are the average of those collected from a number of reliable manufacturers and are self-explanatory, though their import may be better grasped from the result of Table VIII. later referred to.

Tables V. and VI. are tables similar to Table IV., but refer to cooking ovens and utensils. Again, the results can be fully appreciated by inspection of the tables and reference to the footnotes provided, but to further facilitate comprehension, Table XII., which is exactly analogous to Table VIII., may be referred to. In Tables V. and VI. ovens are classified by their cubic feet of available cooking space, the usual classification—"sufficient for *n* persons"—being very vague and entirely dependent on what these persons deem a sufficiency.

The particulars given regarding the energy consumption of the various sizes of ovens are very interesting, and their study is facilitated by representing the results graphically. In determining the energy consumption of the electric stoves, it should be remembered that "full heat" for one-third the cooking period and "one-third full heat" for the remainder thereof usually suffice (see Table XIII.). The gas, coal, and oil consumptions given are mean values over the whole period of operation.

TABLE VIII.—COSTS OF INSTALLATION OF TWO PARTICULAR SYSTEMS, USING VARIOUS METHODS AVAILABLE.

Case I.—Four 1000c.ft. rooms, two used regularly, two intermittently.

Case II.—Four 4000c.ft. rooms, used continually, four 1000c.ft. rooms, used intermittently.

Electric:—

CASE I.	£	s.	d.		CASE II.	£	s.	d.
2, 1000 watts each ..	4	10	0	... Radiators ...	4, 1000 watts each ...	9	0	0
2, 1000 „ „ ...	4	10	0	... Convectors ...	4, 1500 „ „ ...	11	15	0
2—1 per radiator ...	1	0	0	... Screens ...	4—1 per radiator ...	2	0	0
Four (at 3/-)... ...		12	0	... Wall plugs ...	Eight (at 3/-)... ...	1	4	0
100ft.	1	10	0	... Cable to plugs ...	200ft.	3	0	0
Total	£12	2	0		Total	£26	19	0

Steam :—INAPPLICABLE.

	£	s.	d.
Boiler (Heating capacity about 14,000c.ft.)	20	0	0
Steam Mountings	5	0	0
Flue*	1	0	0
Pipe (200ft. of 3in. pipe)	31	13	6
Four valves (at 35/- each)	7	0	0
Bends, Nipples, &c.† (20 nipples at 4/-, 18 bends at 10/-, 12 flanges at 6/-)...	16	12	0
Radiators— 2 4000c.ft., 4 1000c.ft.	18	0	0
Lagging and Miscellaneous	2	5	0
Total	£101	10	6

---

* As in the cases of coal and gas below, it is assumed that a chimney already exists which can be connected to the boiler or stove by the use of say 6ft. of flue pipe of suitable diameter. The installation building costs, which can be saved by the use of electricity, have been dealt with separately, and can be allowed for above if so desired.

† This item must vary considerably with the exact lay-out of each scheme, but in all cases there is here assumed one nipple per 10ft. of pipe, three bends per room (probably five or six will be necessary in many cases), two flanges per radiator. In the case of water pipes socket joints are assumed.

Independent Gas-Steam Units:—

CASE I.	£	s.	d.		CASE II.	£	s.	d.
4, 1000c.ft. capacity	12	0	0	Gas-steam stoves*	2, 4000c.ft. capacity	11	0	0
	—			„ „	4, 1000c.ft. „	12	0	0
60ft. ¾in. pipe	1	15	0	Gas pipe	100ft. ¾in. pipe	2	18	6
Quantities as above	0	19	6	Bends, nipples, &c.	Quantities as above	1	10	0
4, 6ft. each	1	16	0	Flue Pipes	6, 6ft. each	2	14	0
4	0	14	0	Gas Valves	6	1	1	0
Total	£17	4	6		Total	£31	3	6

* Here, as in all these estimates, the cheapest stoves, &c., available, consistent with ordinary good finish, are chosen. A uniform standard of quality is preserved throughout.

Hot-water System:—

	£	s.	d.			£	s.	d.
5000-6000c.ft. capac.	6	0	0	Boiler	12-13,000c.ft. capacity	13	0	0
120ft., 4in. diam.	27	10	0	Piping	200ft., 4in. diam.	45	17	0
2 at £1	2	0	0	Valves	4 at £1	4	0	0
As before	40	0	0	Bends, Sockets, &c.	As before	63	0	0
4, 1000c.ft. at £2 5/-	9	0	0	Radiators	2 4000 & 4 1000c.ft.	18	0	0
	1	10	0	Lagging, Air Cocks and Miscellaneous		2	0	0
Total	£86	0	0		Total	£145	17	0

Coal:—

	£	s.	d.			£	s.	d.
	—			Grates †	4, 2000c.ft. capac. each	24	0	0
4, 1000c.ft. capacity	12	0	0		4, 1000c.ft. „ „	12	0	0
Total	£12	0	0		Total	£36	0	0

† If of "patent" construction the cost per grate will be £8 and upwards.

Charcoal:—

	£	s.	d.			£	s.	d.
4, 1000c.ft. capac.	5	0	0	Stoves	4, 2000c.ft. capac.	10	0	0
					4, 1000c.ft. „	5	0	0
4 at 17/-	3	8	0	Bases	8 at 17/-	6	16	0
Total	£8	8	0		Total	£21	16	0

Gas Stoves (with flues):—

	£	s.	d.			£	s.	d.
4, 1000c.ft. capacity	8	0	0	Stoves	4 2000c.ft. & 4 1000c.ft.	18	0	0
4 at 17/-	3	8	0	Bases	8 at 17/-	6	16	0
60ft. ½in. pipe	1	5	0	Pipe	100ft. ¾in. pipe	2	18	6
4	0	14	0	Valves	8	1	8	0
4, 6ft. each	1	16	0	Flues	8, 6ft. each	3	12	0
2 at 10/-, 2 at 5/-	1	10	0	Guards	4 at 15/-, 4 at 7/6	2	10	0
Total	£16	13	0		Total	£35	4	6

Gas Stoves (*without flues*) :—

CASE I.					CASE II.			
	£	s.	d.			£	s.	d.
4, 1000c.ft.	12	0	0	Stoves	4, 2000c.ft. & 4, 1000c.ft.	32	0	0
4 at 17/-	3	8	0	Bases	8 at 17/-	6	16	0
As above	1	5	0	Pipe	As above	2	18	6
4	0	14	0	Valves	8	1	8	0
As before	1	10	0	Guards	As before	2	10	0
Total	£18	17	0		Total	£45	12	6

Oil :—

	£	s.	d.			£	s.	d.
4 at 35/-	7	0	0	Stoves	4 at £2 10, 4 at £1 15	17	0	0
4 6ft.	1	16	0	Flue	8 6ft.	3	12	0
4 at 10/-	2	0	0	Bases	4 at £1 & 4 at 10/-	6	0	0
Total	£10	16	0		Total	£26	12	0

Central Stove (*coal*) *distributing hot air* :—

	£	s.	d.			£	s.	d.
	5	0	0	Stove (cost varies enormously with finish and style)		12	0	0
	1	10	0	Base		2	0	0
	2	0	0	Air Inlet Pipe		2	0	0
(2 per stove)	0	12	0	Fireclay Pipes		0	12	0
100ft. C.I. pipe at 1/3 ft.	6	5	0	Ducts	200ft. C.I. pipe at 1/6 ft.	15	0	0
12	3	12	0	Bends	16	4	16	0
	2	10	0	Pilot Stove		2	10	0
5	0	10	0	Cleaning Doors, 10		1	0	0
5	1	5	0	Wall or Floor Flanges, 10		2	10	0
	0	10	0	Flue (assuming use existing chimney)	6ft. pipe	0	12	0
	0	8	0	Ashpan		0	12	0
	1	15	0	Inlet Pipe and Registers, &c.		2	10	0
	0	13	6	Special Stoking Tools and Scuttle		0	13	6
6	6	0	0	Air Valves to each Room, 10		10	0	0
Total	£32	10	6		Total	£56	15	6

With regard to kettles, saucepans, and urns, the consumption of the electric units is stated and the cost of installation is compared with that of utensils or use with coal, gas, or oil. The electric utensils referred to are of the self-contained type (*i e.*, include their own heating elements); the utensils used with "hot plates" may, of course, be of the ordinary gas or coal pattern, but the objection to them on the score of inefficiency is dealt with later. The relatively high cost of these self-contained units is one of the greatest bars to the extension of the domestic use of electrical energy, and a plea may here be again reiterated to manufacturers, to place on the market reliable, substantial apparatus at a lower figure than that required for the ornamental and often flimsy designs now so prevalent. The ill-effect of these high prices, on the cost of installation of an equipment, is well shown in Table XII., but that this does not extend to the annual cost of operation, depreciation, &c., is shown by Table XIII. In the case of urns and tank boilers, electrical apparatus is not at such a heavy disadvantage as regards capital cost. Tank boilers are compared in Table VI., and it will be seen that there are grounds, though not so extensive as usually represented, for the complaint that water heating by electrical energy is very expensive. This complaint should not exist, since the amount of energy required to raise 1lb. of water through a given temperature range is perfectly definite no matter what form of energy be employed to effect the heating. The very high efficiency of electrically heated utensils should more than compensate for the loss of efficiency due to the several energy conversions at the central station.

TABLE IX.—SUMMARY OF INSTALLATIONS DETAILED IN TABLE VIII.

Case I.—Four 1000c.ft. rooms, two used continually, two intermittently.

Case II.—Two 4000c.ft. rooms, used continually, four 1000c.ft. rooms, intermittently.

Results of costs of installation, neglecting all building costs, costs of structural alterations, fixing apparatus, carriage, &c.

Running costs are compared elsewhere.

Method of Heating.	Cost of installation on above assumptions.					
	Case I.			Case II.		
	£	s.	d.	£	s.	d.
Electric Radiators and Convectors*	12	2	0	26	19	0
Steam Pipes and Radiators	Inapplicable.			101	10	6
Independent Gas Steam Units .	17	4	6	31	3	6
Hot Water System (coal fuel) ..	86	0	0	145	17	0
Coal Grates	12	0	0	36	0	0
Higher Efficiency ditto	32	0	0	64	0	0
Charcoal Stoves	8	8	0	21	16	0
Gas Stoves (with flue)	16	13	0	35	4	6
Gas Stoves (without flue)	18	17	0	45	12	6
Oil Stoves	10	16	0	26	12	0
Central Slow Combustion Stoves ..	32	10	6	56	15	6

* Using convectors in those rooms permanently occupied and where the volume to be heated much exceeds 1000c.ft.

The comparison between electric, oil, and gas "geysers" is of interest, though perhaps of little importance, the load being one that would hardly be desired by the central station engineer and the apparatus being in all cases very inefficient from the point of view of the consumer. There is no doubt, however, that the electric geyser is considerably safer in operation than oil or gas types, particularly owing to the absence of poisonous fumes and to the easy avoidance of explosions by the use of fusible cut-outs. By the provision of a suitable number and size of heating elements there is, of course, no limit to the rate of boiling which can be effected. At the very rapid rates, however, the efficiency of the whole will further suffer. With regard to the cost of use per hour in normal designs the electric type compares very favourably with the oil types.

Table VII. gives the cost of the accessories required by the various systems, and the immense superiority of electric heaters in this respect will be evident. The data of Table VII. are self-explanatory as they stand, but the exact effect of these costs in any particular equipment is best shown in Table VIII., which compares the total costs of installation of room heating systems in two typical cases, viz.:—

1. That of four 1000c.ft. rooms (10ft. × 10ft. × 10ft., say), of which two are used regularly and are therefore heated by convectors, while two are used intermittently only and are therefore equipped with radiators.

2. That of two 4000c.ft. rooms (say 28ft. × 12ft. × 12ft.) used continuously, and four 1000c.ft. rooms used intermittently.

A probable length of distributing pipe or duct is assumed in those cases where necessary, and the control valves, guards, and other accessories assumed are as shown.

The final results obtained are summarised in Table IX, these costs being exclusive of

TABLE X.—COST OF RENEWALS.

	Electricity			Steam (coal-fired)		Steam (gas-fired)		Hot Water (coal-fired)		Coal Grates		Charcoal	Gas (with flues)		Gas (no flues)		Oil		Central Coal Stove
	250 Watt Lamps	250 W. Convector Strips	Depreciation*	Labour, &c.†	Depreciation*	Labour	Depreciation*	Labour†	Depreciation*	Fire Bricks	Chimney Sweeping	Depreciation*‡	Asbestos	Depreciati'n*‖	Chimneys	Burners	Wicks	Depreciation*	Depreciation*§
Cost	4/-	1/6	0.23/-	73/-	7/6	10/-	3/9	73/-	2/10	2/-	2/6	0.94/-	3/-	0.7/-	1/-	5/-	6d.	1/9	9d.
Life (hrs.)...	3000'	10,000	at 1%	Per 1000 hrs.	at 5%	Per 1000 hrs.	at 10%	Per 1000 hrs.	at 4%	2500 hours	2000 hours	at 7½%	2000 hours	at 4%	700 hours	3000 hours	300 hours	at 10%	at 2½%
Total Cost per 1000 hours use	Labour nil 5/7	10d.	— —	80/6	—	13/9	—	75/10	—	12/-	—	11/-	Labour nil 2/3	—	8/4½	—	17/5	—	10/9
Remarks ...	'This life is longer than of carbon lamps because blackening no longer matters.		—	—	—	—	—	—	—	Labour 10/- per 1000 hours use.		Labour 10/- per 1000 hrs. use.	Asbestos fibre or bricks.		Labour 5/- per 1000 hours use.		Labour 15/- per 1000 hours use.		Labour 10/- per 1000 hrs. use.

† Including chimney sweeping, stoking, and general attendance. It is very hard to determine this cost exactly, but the estimates given in the case of steam and water heating assume that a man paid at the rate of 25/- per week of 54 hours is occupied 3½ hours per day attending to the apparatus (when latter is in operation, 24 hours per day).

‡ Depreciation is the chief charge against these stoves, and owing to the long-maintained intense temperature it is a fairly serious charge. Labour in this case, as in coal or oil stoves, is taken to work out at about 1½d.-2d. per day per stove or grate.

‖ This depreciation, though fairly low, is considerably higher than that of an electric radiator or convector.

§ There is the usual wear and tear on thin flue pipes, stoking tools, grate linings, &c., which is however fairly allowed for by a 2½ per cent. depreciation charge.

* Depreciation is reckoned on the installation cost per 1000c.ft. (At a capacity of 1000c.ft., see Table IV.)

TABLE XI.—COST OF FUEL, &c., AND TOTAL COST PER 1000 HOURS OF WARMING 1000C FT. BY VARIOUS METHODS.

	Electric.				Steam (coal-fired).		Steam (gas-fired).	Hot Water (coal-fired).		Coal Grates.		Charcoal.	Gas (with flues).	Gas (without flues).	Oil.		Central Coal Stove.	
	Radiator.		Convector.															
Consumption per 1000 hours.‡	1000 B.T.U.		1000 B.T.U.		2000lb.‖		8000c.ft	1000lb.‖		3000lb.		125lb.	17000c.ft.	20,000c.ft.	95 gallons		800lb.†	
Rate of fuel or energy.§	¾d. per unit	1d. per unit	¾d. per unit	1d. per unit	15/- per ton	25/- per ton	2/9 per 1000 c.ft.	15/- per ton	25/- per ton	18/- per ton	28/- per ton	16/- per cwt.	2/9 per 1000c.ft.	2/9 per 1000c.ft.	8d. per gallon	1/-per gallon	15/- per ton	25/- per ton
Cost (fuel) per 1000 hours.	62/6	83/4	62/6	83/4	13/6	22/6	22/-	6/9	11/3	24/-¶	37/6¶	18/-	46/9	55/-	63/6	95/-	5/6	9/-
Cost renewals per 1000 hours.*	5/7	5/7	10d.	10d.	80/6	80/6	13/9	75/10	75/10	12/-	12/-	11/-	2/3	8/4½	17/5	17/5	10/9	10/
Total Cost per 1000 hours (approx.).	68/-	89/-	63/4**	84/2**	94/-	103/-	35/9	82/7	87/-	36/-	49/6	29/-	49/-	63/6	81/-	112/6	16/3	19/9

* Including depreciation, &c. (see Table X.).

‖ Would be less in cases where a very large central plant is installed.

‡ See Table III.

§ The rates here given cover the extremes likely to be met in practice. If pure anthracite be burnt the cost may be 30/- per ton. Gas charge has been obtained as explained in lighting section.

† This estimate is probably on the low side.

¶ Better quality coals for domestic use.

** See remarks on these costs in letterpress.

building and structural alterations, fixing of apparatus, carriage, &c. It will be seen from this summary that the order of economy of installation cost is, in the two cases:—

	Case I.	Case II.
Cheapest.	Charcoal Stoves.	Charcoal Stoves.
	Oil Stoves.	Oil Stoves.
	Ordinary Coal Grates.	Electric Radiators and Convectors.
	Electric Radiators and Convectors.	Independent Gas Steam Units.
	Gas Stoves (with flue).	Gas Stoves (with flue).
	Independent Gas Steam Units.	Ordinary Coal Grates.
	Gas Stoves (without flue).	Gas Stoves (without flue).
	Specially high-efficiency Coal Grates.	Central Slow Combustion Stoves.
	Central Slow Combustion Coal Stoves.	High-efficiency Coal Grates.
	Hot Water System (coal fired).	Steam Pipes and Radiators.
Most Expensive.	—	Hot Water System (coal fuel).

Thus it will be seen that the electric heating scheme is considerably the cheapest in first cost if we exclude charcoal and oil stoves, both of which are unhealthy methods of heating, the latter in all cases and the former if its flues should leak (in which case the escaping gases have frequently been fatal in their results).

The above order of economy has naturally to be considerably modified when the costs of operation are included (see Tables X. and XI.).

In Table X. suitable depreciation allowances are made to cover the renewal charges for coal and steam systems, &c., these renewals being of too variable a nature from year to year and in various services to allow them to be covered by any other than an average depreciation charge. In the electrical units, lamps are the only renewals required, depreciation of the rest of the equipment being negligible. Owing to the considerably higher temperature to which the frame, &c., of gas, oil, and coal stoves is exposed, a higher depreciation must be assumed as shown.

The basis on which the labour charges are estimated is stated in a footnote to Table X. The labour charges for electric stoves and gas stoves *with* flues are negligible; for coal and oil and *flueless* gas stoves the cost of labour by an ordinary domestic servant is estimated, while for steam and water heater the attendance of a more or less skilled man is assumed.

In this table depreciation is based on the data of Table IV., the whole of the charges being reduced to 1000c.ft. heating capacity. The results of Table X. are utilised in Table XI., in conjunction with the figures of Table III., to estimate the total cost of warming a room of 1000c.ft. capacity for 1000 hours by various methods. Though this table cannot include the cost of relighting coal fires and all similar indirect costs, yet it includes, with fair accuracy, the charges for energy, renewals, depreciation, and general labour.

In the case of coal, oil, and electricity two rates per ton, per gallon, and per B.O.T. unit respectively are assumed, while for gas the average rate already arrived at in the lighting section (*q.v.*) is assumed. As a result of Table II. the order of merit already established as regards capital cost may be modified as below, when that possibly more important amount—total cost of operation—is concerned.

For the case assumed, that of an ordinary 10 × 10 × 10 room, the new order is :—

Cheapest.	Central Coal Stove.
	Charcoal Stove.
	Gas-fired Steam Units.
	Ordinary Coal Grates.
	Gas Heaters (with flues).
	Electric Convectors.
	Gas Heaters (no flues).
	Electric Radiators.
	Oil Heaters.
	Hot Water Heaters.
Most Expensive.	Coal-fired Steam System.

In this classification the electric and flueless gas systems have practically equal costs, but the immense hygienic superiority of the electric system, apart from the less damage to furniture, &c., is obvious. The final remodelling of the above classification, to take account of all the indirect influences referred to later, is a very difficult matter, depending as it does so largely on the individual conditions of each case.

Table XII. is exactly analogous to Table VIII., but refers to a cooking equipment. Little additional comment is required to this table beyond that given in the footnotes. The relatively high cost of installation of the electrical equipment (between three and four times that of the coal, gas, and oil sets, which are all very nearly equal) has been already explained and the remedy stated.

TABLE XII.—COSTS OF INSTALLATION OF TYPICAL EQUIPMENTS.

ARTICLE	CAPACITY	Cost for operation by											
		Electric			Gas			Coal			Oil		
		£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Oven	1.5c.ft.	6	2	6	3	5	0	4	0	0	2	18	0
„	4.0c.ft.	7	15	0	7	15	0	8	10	0	9	0	0
Copper Kettle ..	2 pts.	0	15	0	0	3	0	0	3	0	0	3	0
„ „ ..	4 pts.	1	15	0	0	7	0	0	7	0	0	7	0
Saucepans—*													
Enamel ..	1 pt.	†0	16	0	0	3	0	0	3	0	0	3	0
Copper ..	2 pts.	†1	5	0	0	7	0	0	7	0	0	7	0
Enamel ..	4 qts.	†2	0	0	0	4	0	0	4	0	0	4	0
Enamel ..	6 qts.	†2	5	0	0	6	0	0	6	0	0	6	0
Plate Warming Box ..	—	1	0	0	included above						0	15	0
Frypan ‡ and Cover	8¼" dia.	2	0	0	0	6	0	0	6	0	0	6	0
Griller ‖	9" by 12"	3	0	0	0	12	0	0	2	6	0	2	6
Total with Small Oven ..		20	18	6	5	13	0	5	18	6	5	11	6
„ „ Large Oven ...		22	11	0	10	3	0	10	8	6	11	13	6

* In the electrical costs these vessels are self-contained, *i.e.*, heating elements are permanently fixed in base, this being much more efficient than hot-plate arrangement. Prices of latter are given elsewhere and may be substituted above if desired. (In that case only ordinary cooking vessels need be used.)

† These costs are average only—see Tables V. and VI. for details.

‡ The consumption of this utensil (electric) is 360 watts and 787 watts in the low and high heats respectively. The corresponding gas, coal, and oil consumptions may be determined by use of Table I.

‖ The consumptions of this utensil on the three heats provided (in the electrical form) are 240, 650, and 1000 watts respectively. The corresponding coal, gas, and oil consumptions may be found by reference to Table I. (second section). That Table I. is actually favourable to gas may be seen from the fact that it gives the gas consumption for a griller similar to the above as 17.2c.ft. per hour, whereas the makers state a consumption of 24c.ft. per hour.

In view of these results it is all the more striking to find that, using them in Table XIII., the total cost of use per year for electric stoves is only very slightly higher than for gas stoves, while it is considerably less than for oil stoves. Coal stoves are considerably cheaper than any of the other systems, but are much less convenient and flexible in operation. Table XIII. is based on the assumptions set out below:

TYPICAL COSTS OF USE OF VARIOUS COOKING SYSTEMS.

Assumptions made:—Consumptions as below (see also Table V.).

The consumptions of gas, coal, &c., are mean values applicable over the whole time of cooking, but in the case of the electric ovens and utensils "full heat" may be employed for $\frac{1}{3}$ total time of use, "$\frac{1}{3}$ heat" then usually sufficing for the remainder ot the operation owing to the excellent heat insulation obtainable.

The average times of use per operation of cooking utensils is found to be:—

Kettles	15mins.
Urns (1 quart)...	15 „
Urns (6 quarts)	40 „
Disc stove ...	30 „
Frying pans ...	15 „
Grid, broilers ...	20 „
Ovens, 45mins. to 1½hrs.—	

while the use of the chief utensils per 24 hours is found to be roughly:—

Kettles, 4hrs.; ovens, 4hrs.; boilers, 10hrs.; grillers, toasters, &c., 2hrs.; urns, &c., 3hrs. in 24hrs.

Any accurate estimate of these periods is of course very difficult, if not impossible, but the above figures endeavour to make allowance for the variations in different

TABLE XIII.—§ COST OF USE OF VARIOUS COOKING SYSTEMS PER YEAR, INCLUDING DEPRECIATION, BUT EXCLUDING RENEWALS AND LABOUR CHARGES.

System of Cooking	Price of Energy.	Ovens.			Kettles.			Boilers, &c.*			Urns.			Grillers, &c.			Total Cost of Fuel or Energy.	Capital Cost of Installation. ‡	Depreciation.†	Total Cost of Use per Year.
		Hours of Use.	Consump. of Energy.	Cost of Energy.	Hours of Use.	Consump. of Energy.	Cost of Energy.	Hours of Use.	Consump. of Energy.	Cost of Energy.	Hours of Use.	Consump. of Energy.	Cost of Energy.	Hours of Use.	Consump. of Energy.	Cost of Energy.				
				Pence.			Pence.			Pence.			Pence.			Pence.	Pence.	£ s. d.		£ s. d.
Electrical ..	1d. unit.	487 at 1500 watts. 973 at 500 watts.		730 486	1460	800 watts	1165	1217 at 1000 watts 2433 at 350 watts		1217 850	365 at 1500 watts. 730 at 500 watts.		548 365	243 at 1000 watts. 487 at 300 watts.		243 146	5750	21 0 0	at 1% 50d.	24 3 4
Coal	20/- ton.	1460	7lb. per hr.	1095	1460	2.40lb. per hr.	376	3650	2.97lb. per hr.	1163	1095	445lb. per hr.	523	730	2.97lb. per hr.	233	3390	8 10 0	at 3% 61d.	14 7 5
Gas	2/9 1000 c.ft.	1460	25.7cft. per hr.	1245	1460	13.8c.ft. per hr.	670	3650	17.2c.ft per hr.	2070	1095	25.8c.ft per hr.	934	730	17.2c.ft. per hr.	415	5334	8 10 0	at 5% 102d.	22 13 9
Oil	‖ 9d. gallon	1460	1.75 pts. per hr.	2860	1460	0.445 pt. per hr.	730	3650	0.557 pt. per hr.	2290	1095	0.835pt. per hr.	1030	730	0.557	457	7367	9 5 0	at 5% 111d.	31 3 2

* Including stewpans and saucepans. † See letterpress for notes regarding depreciation.
‡ See Tables V. and XII. The capital cost here given refers to a more elaborate equipment than assumed in the other parts of the table.
‖ This figure is assumed as a good mean value for town and country.
§ All these energy costs, of course, depend directly on the price of whichever form of energy is used, per unit. If the rates assumed do not apply to any particular case, the costs for that case may be evaluated from the above by simple proportion.

households and to allow for the different seasons of the year (*i.e.*, the figures are taken on a yearly average).

Per year of ordinary use these figures amount to:—

Kettles, 1460hrs.; ovens, 1460hrs.; boilers, 3650hrs.; grillers, toasters, &c., 730hrs.; urns, &c., 1095hrs. per year: which figures are used in the estimation of the total cost per year of various systems as given in Table XIII.

In the latter table depreciation and repairs, &c., are reckoned at the percentage stated on the capital costs of installation as given in Table XII. Costs of renewals are not included, since in the electrical apparatus they are practically nil, while in the other systems they are so variable as not to be capable of accurate estimation. Some aid in this respect however is given by Table XI.

In Table XIII. the capacities of ovens, &c., assumed are:—

Oven	3c.ft. available space.
Kettle*	3 pints.
Urn	2 gallons.
Tank boiler, saucepans, &c.	1.5 gallon.†

Grilles, &c., of ordinary domestic size.

For those cases in which sufficient data regarding energy consumption are not given in Table VI., use is made of the second section of Table I. and of certain data in Table XIV.

Assuming the average energy rates shown in the table, it will be seen that the order of economy, reckoning cost of energy + depreciation, is:—

		Relative costs.
Cheapest.	Coal systems...	0.59
	Gas systems ...	0.94
	Electric systems	1.00
Most expensive.	Oil systems ...	1.29

With regard to the percentage depreciations allowed, the same remarks apply as already made in the case of the room-heating appliances. So little is the deterioration of the electrical apparatus that the renewal period would probably be determined solely by the introduction of newer and more efficient equipments. This fact must be borne in mind when estimating the depreciation required by any electrical apparatus. On these grounds the depreciation actually allowed in Table XIII. for the electrical apparatus should probably be higher, but the effect on the total annual cost would be very slight, and may be calculated for any particular case from the data given.

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* It is assumed that kettles are used at maximum heating rate throughout, all the other implements being used ½ time at full heat and the rest at ¼ heat.

† This figure is taken as the equivalent total of all saucepans, &c.

As a fitting conclusion to the preceding elaborate system of cost tables worked out on the most general basis possible, Table XIV. may be studied; this table sets out *actual working results* of numerous tests comparing electrical, coal, gas, and oil cooking systems. The date and authority of each set of tests are stated, and the essential results are tabulated. It is to be noted that the most recent tests indicate that electric cooking is already practically equal to gas cooking so far as cost of energy is concerned, while it has never been questioned that it is far superior from the hygienic point of view. Our progress has therefore reached that stage in which it only remains to reduce the capital cost of electrical heating apparatus (of the possibility of which there can be no doubt) in order to make electric cooking the cheapest and best in every way.

With regard to room heating, electric heaters have more leeway to recover: the capital cost of the heating units is already at a very low value (see Tables IV. and IX.), hence the reduction of the total cost per 1000c.ft. per hour of heating can only depend on the more efficient distribution of heating units and on the *more efficient design of rooms.* The importance of the latter is as yet imperfectly grasped by designers; its effect on the efficiency of a heating system will be referred to more fully later.

Cost of Building.—This cost is one of considerable importance in the present case, and the chief items in which electrical and other sources may be compared under this heading are:—

1. Cost of chimneys.
2. Cost of fireplaces.
3. Cost of coal stores, oil tank, chambers, &c.
4. Cost of hot-air chambers, stoking cellars (with steam or hot water systems).

Various contractors and builders have expressed the opinion that the saving in the initial construction of a house built with the intention of using electric heating throughout, and hence built without chimneys and fireplaces, would be from £30 to £40 in a £1000 villa. This does not allow for the saving in overmantels, &c.; hence the total saving would amount to from £60 to £70, or even more, were the shape of the house such that two or three chimney-stacks would be necessary when using coal fires. This economy alone would go far towards the installation of a very complete electric heating and cooking equipment, and as it is only in prime cost that electric heating proves rather expensive, this point should influence all builders of new residences. The various other economies in subsequent renovations, &c., would certainly more than compensate for any excess of electric working costs over those for gas or coal.

The cost of building large fireplaces would be entirely avoided were coal fires abolished, and very artistic alcoves to contain electric radiators could be built, if so desired, at a nominal cost, or heaters placed in the centre of the room could be employed. With gas heaters the necessity of providing flues to carry off the products of combustion largely prevents this economy, *i.e.*, that of abolishing chimneys, for if the latter be abolished flues must still be driven through the walls, and usually then form a very ugly excrescence.

The cost of building coal stores is quite considerable even in the smallest houses, where its abolition would result in a saving of £5 to £10 in the building cost of the house. In larger establishments the economy would be correspondingly greater, being £30 to £50 where a really elaborate fuel house is built to enable the economical purchase of fuel in bulk. Oil stores, being usually subterranean (in compliance with the fire insurance company's requirements), are even more expensive, and in spite of the possibility of storing oil in about half the space required by the equivalent amount of coal, it will be found that a fireproof oil store costs about twice as much to construct as the equivalent coal house.

Hot-air chambers for those central-heating systems in which the air in a central brick chamber is heated and then distributed through ducts to all the rooms to be heated cost about 25 per cent. more than coal houses to build, owing to the better building required and to the necessity of fitting the chamber in neatly somewhere in the house.

Besides this there is the cost of "building-in" air distribution ducts, which should be of earthenware if great loss by conduction is to be avoided, and of providing and driving the electric fan which is usually relied upon to distribute the hot air. In few large schemes can convection currents alone be depended on to distribute the heated air, but an alternative to the installation of fans is afforded by the "pilot" stoves placed one at the end of each horizontal length of distribution duct to induce the necessary air current along the latter (see also Table VIII.).

To illustrate the cost of these hot-air chambers. In a particular case the size of chamber required was 6ft. × 7ft. × 5ft. *i.e.*, area of walls = 214 square feet; hence, assuming a 9in. brick wall and standard size of brick 9in. × 4½in. × 3in., the number of bricks required $= 2 \times \frac{214 \times 144}{27} = 2280$, or, say, 2500, which, at £2 5s. per thousand, cost £5 12s. 6d, and, allowing £3 for labour and miscellaneous costs, the total cost of the chamber = £8 15s. (say). This estimate refers to the cost of building at the

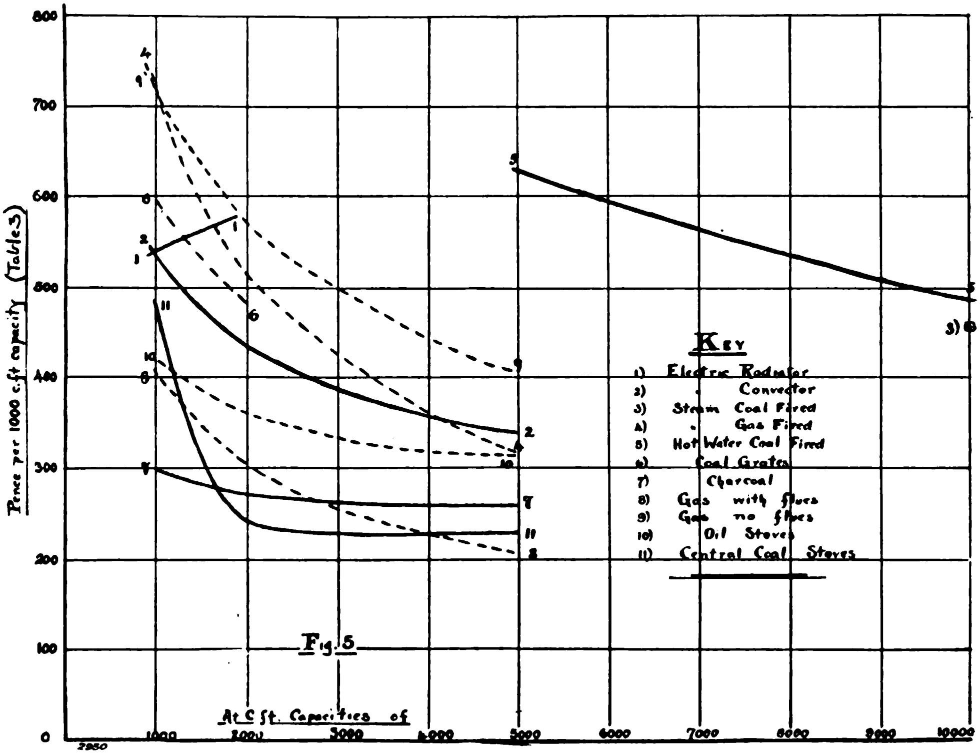

Fig. 3.

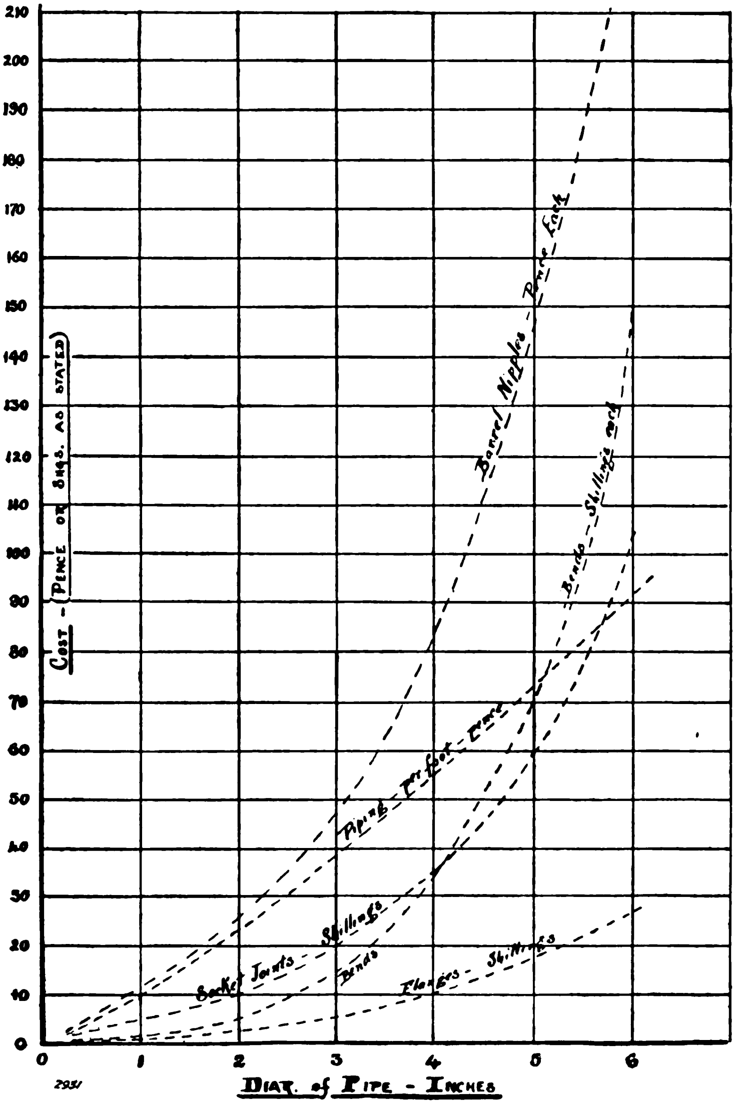

FIG. 4.

usually leave a considerable balance to pay off any increase in the operating charges for some time to come.

Efficiency Considerations. — Much of this section, as originally schemed, has already been dealt with, while some of the remainder cannot conclusively be dealt with until later sections have been treated. Such are the intermeshings of a subject of this nature and so many and complex the lines along which its development has run that it is impossible to arrange such a system of classification as will enable each heading in turn to be fully dealt with. Indeed such "pigeon holing" would not be desirable. As the factors concerned are interwoven in practice, so let them appear here, the tangled skein being, however, so far unravelled as to enable a clear view of the subject. It is well that the many different bearings, which apparently unimportant points have on the results obtained, should be realised.

Certain figures relating to the efficiency of design of various heating agencies have been already given in Table III., while certain others are deduced in Table XV.

It will be seen from Table III. that electric room-heaters are, on the whole, the most satisfactory available as regards volume

time of erecting the house; if it be effected after completion of the house the cost will be much higher owing to the difficulties of working and damage to the rest of the property, and so on.

Hence it is apparent that if it be known when building that electric heating and cooking is to be employed, very considerable economies can be effected in the building costs, which economies will wholly cover the cost of installing the electric equipment and

TABLE XIV.—TABULATED RESULTS OF VARIOUS TESTS (FROM VARIOUS SOURCES). ACTUAL RESULTS OF DIFFERENT HEATING AGENTS (*NOT* REDUCED TO ANY COMMON RATE OF ENERGY SUPPLY).

SOURCE OF INFORMATION.	ELECTRICAL.				COAL.				GAS.				OIL.				REMARKS.
	Performance,	Energy Consumed. Units.	Price per unit of energy.	Cost of given Performance.	Performance.	Weight Coal Burnt.	Price Coal per ton.	Cost of Performance.	Performance.	Amount Gas Burnt. C. ft.	Price Gas per 1000c.ft.	Cost of Performance.	Performance.	Amount Oil Burnt.	Price Oil per gallon.	Cost of given Performance.	
Personal tests					50 galls. water to 120°-140° F	35lb	20/-	3.76d.	Dinner for 6 people	50	3/6	2.10d.					
Personal tests									5 pints water boiled	3.5	3/6	0.147d.					
Private tests	Dinner for 8 people	4.75	1d.	4.75d.													
Miss Seaver (Amer.)	General cooking over given period	1.032	2.0d.	2.064	As in electrical case	10.5lb	28/-	1.83d.	As in previous tests	20	4/-	1.00d.	As in previous cases	0.0832 gal. 0.078	7.5d. 7.0d.	0.60d. 0.55d.	Gasoline Kerosene
Mr. Wilkinson	22lb. meat 2 pudding	8.00	1.0d.	8.00													
Mr. Wilkinson	87lb. meat	14.00	1.0d.	1s. 2d.					† 500lb meat	400 per hr.	2/11	9/4					
Mr. Wilkinson	41.5lb. meat	9.00	1.0d.	* 9d.													
Mr. Britton	Per pint water boiled	0.0867	1.5d.	0.13									Rippingille stove	0.0169	6.5d.	0.11d.	

* In this case half-heat was used after 1.5 hours (whole operation took four hours). This case illustrates the economy of the double or triple "heats" available.

† Meat in six pieces 80lb. to 85lb. each; time to cook, 8 hours; cost gas per hour = 1s. 2d. (Note that the costs of cooking electrically and by gas are here equal.)

and weight per 1000c.ft. heated as well as regards capital cost per 1000c.ft. heated. In the matter of *volume* economy gas stoves are about as satisfactory as electric radiators, but their *weight* is considerably greater. The charcoal stove effects considerable economy of volume occupied, but has very serious disadvantages elsewhere referred to (including the necessity of a special fuel and the danger to health).

Curves showing the weight and capital cost per 1000c.ft. heating capacity of various systems are given, Figs. 1 and 3, and afford a clear graphical interpretation of the tabulated data. Table XV. also presents features of interest in that it shows the small overall bulk of an electrical cooking-stove of given available capacity. The asbestos, sawdust, or vacuum lining provided as a heat insulator to most electric ovens greatly increases the efficiency of the oven without creating a large volume of inactive space as might be feared. The stoves dealt with in Table XV. are of thoroughly average design and the low value of the ratio

$$\left(\frac{\text{Overall volume}}{\text{Effective volume}}\right)$$

for electric stoves is to be noted. For gas ovens this ratio is about 10 per cent. higher, while for oil and coal ovens it rises to twice or thrice the value.

TABLE XV.—EFFICIENCY OF DESIGN OF VARIOUS STOVES AT PRESENT USED.

Type of Stove.	Approximate Capacity (useful).	Dimensions.		Volume.		Ratio—
		Inside.	Outside.*	Effective.	Overall.	Overall Vol. / Useful Vol.
Electric	1.25	16" × 10½" × 13"	18" × 12½" × 16"	1.27c.ft.	2.09c.ft.	1.64
Gas	3.50	24½" × 15" × 16"	32" × 18" × 18"	3.39	6.00	1.78
Oil	0.25	9" × 8" × 6½"	13¾" × 14" × 8¾"	0.271	0.970	3.57
Oil	1.00	13½" × 12" × 9½"	17¼" × 12¾" × 20"	0.89	2.55	2.87
Oil	2.75	22" × 15" × 15"	36" × 18¼" × 25¼	2.86	9.60	3.35
Coal	1.26†	12" × 13" × 14"	22" × 15" × 20"	1.26	3.83	3.05
Coal	2.20	17" × 16" × 14"	36" × 27" × 20"	2.2	11.25	5.12
Coal ‡	2 × 2.35 4.70	15" × 15" × 18"	20" × 48" × 30"	4.7	16.65	3.55

* These include the grates in case of coal ovens, but do not include height of kitchener above hotplate.
† A portable stove. ‡ Double-oven kitchener.

Further considering the thermal efficiency of various systems of heating, and means whereby this efficiency may be increased, it may first be noted that it is an established fact that *the efficiency of an ordinary coal grate is only* 12 *per cent. to* 15 *per cent.*, *i.e.*, the heat given out into the room only equals about 12 per cent. to 15 per cent. of the total calorific value of the coal. The remainder of the heat is wasted up the chimney. Gas fires are little better in this respect owing to the necessity of removing the products of combustion as soon as possible.

Various means have been tried of heating air in pipes passing through the flues or, conversely, of winding the flues about in the room for some distance before leading them to waste, but such methods, though certainly effecting some economy, are very inefficient.

The principle of air-jacketing the stove is practically that employed in so many slow-combustion stoves for heating and ventilating a room by drawing in air from outside the house, warming it in the stove jacket, and discharging it to the room. Though this system has remarkably low operating costs (see Table XI.), it is subject to grave disadvantages in other respects (*e.g.*, in capital expense, cost of fixing, and in weight of apparatus).

Providing the rules stated in the section regarding the placing of electric radiators or convectors be observed, the efficiency of the conversion of electrical energy to useful heat will be from 85 per cent. to 95 per cent. in the case of radiators, and 90 per cent. to 97 per cent. in the case of convectors.

Comparing this with the figures given above for coal grates, it will be understood how it is that electric heating can be more economical than direct coal heating, in spite of the triple conversion to which the energy is subjected in the former case. (This triple conversion comprises the conversion of heat to mechanical energy, of mechanical to electrical, and of electrical back to heat: as is well known, we should achieve an immense increase in efficiency could we convert heat energy direct to electrical energy, and on a large scale.)

In order to maintain a temperature gradient, the flue gases in any coal, gas, or oil consuming plant must be rejected at a temperature which is comparatively high compared with that of the surrounding air. This can be done, however, with far less loss of efficiency at a central station employing economisers and superheaters than in the domestic chimney, where all the heat is absolutely wasted, as far as we are concerned, once the gases have passed the grate chimney orifice.

Passing on to the application of electric heating to cooking and water heating, the above remarks again apply, with the additional possibility of effecting further economy by heat insulating the electrical utensils. The electric disc stove or hot plate replaces the gas ring, and by suitably lagging the former all waste analogous to the side flare or reflected downward heat of the gas ring is avoided. The only way in which heat can escape to any appreciable extent is via the material to be heated.

A gas flame beating on to a metal surface is not an efficient method of heating, especially when, as in the ordinary gas stove, any heat once reflected back is lost for ever so far as the vessel is concerned. That gas cooking is inefficient in this manner is proved by the rapid rise of temperature of a room in which gas cooking is proceeding. Where electric cookers are employed the temperature of the surrounding air is not appreciably affected even after several hours' operation.

Though electric disc stoves are a great improvement on gas rings in the matter of efficiency, yet the self-contained electric saucepan or kettle, as the case may be, is far more efficient. In the latter class of utensil the heating coils are embedded in a thin layer of insulating enamel in the bottom of the vessel itself, and are thus in excellent thermal contact with the material to be heated. The enamel used is mechanically strong, an electrical insulator, but a good thermal conductor: a suitable lagging or vacuum chamber is usually formed round the utensil proper, and excellent heat insulation so effected. The efficiency of conduction from wire to liquid in such a case usually exceeds 97 per cent.

When the independent electric disc stove is employed a mechanical or magnetic clamp should always be provided so as to ensure very good contact between the bottom of the vessel and the top of the stove. It is essential that a good thermal contact should be effected, and hence both surfaces must be kept very clean. The slightest trace of grease or dirt or the smallest film of air will decrease the efficiency of the stove by 10 per cent. to 30 per cent.

Temperatures attainable with each form of heater, and points arising from this consideration :—

It is of considerable interest to note the temperatures attainable with various heating agencies, though this point is hardly of such importance in domestic considerations as in the industrial applications treated in the next section of this series of papers.

Considering first the temperatures most desirable in various services, and the ranges of temperature advisable, we have that a healthy room temperature is about 60deg. F., oven temperatures range from 200deg. to 400deg. F., and the temperature of boiling water is, normally, 212deg. F.

As an average figure, it may be taken that a uniform room temperature of about 60deg. F. can be obtained electrically by allowing 1 watt per cubic foot to be heated, *i.e.*, in a room 10ft. × 10ft. × 10ft. we should need 1000 watts to be dissipated, which is usually effected by four 250-watt radiator lamps or convector strips. This allowance provides for a room temperature of 60deg. to 70deg. F., when the open-air temperature is 32deg. F., hence a less liberal allowance would usually suffice in England. To attain higher temperatures more lamps would have to be provided, but the efficiency of the heating would be reduced, the difference of temperature between the source and room being less, *i.e.*, the temperature gradient being less steep.

Where the convector type of heater is employed it may be taken that the above rule (1 watt per cubic foot heated) still holds, though it is possible in some cases, by careful design and under favourable working conditions, to get up to 1.25c.ft. heated to 60deg. to 70deg. F. per watt dissipated or even higher. It is of course obvious that the allowance to be made, whatever the source of energy, depends essentially on the ventilation provided. A room through which a strong current of cool air is continually flowing will need a far greater expenditure of energy to maintain a given temperature than one which is entirely shut off from external air currents.

The temperature of convector strips used for heating a normal room is usually about 260deg. F.; each strip unit is designed to dissipate about 55 watts when at this temperature. If the temperature of the strips be too high the air passing over them is rendered very dry and is technically termed "burnt." Air in this condition is of course very unhealthy. Fortunately, the requirements of health, efficient heating; and long life of strip all coincide in this case.

With coal heating there is practically no limit to the temperature which can be attained in the room or oven by suitably stoking the grate. The same statement also applies to gas and oil stoves, but cannot be regarded as an advantage. Were it desired, a far higher temperature could be obtained electrically than can be approached by coal, gas or oil heating, as shown later, but the possibility of overheating by mere overstoking (absent in the case of electric radiators and convectors) enables very unhealthy conditions to be attained in rooms, or, in cooking, exposes the articles dealt with to considerable risk of burning.

Moreover, when the heating is increased in this manner, vitiation of the surrounding air proceeds correspondingly faster, and the necessary increase in the ventilation supply rapidly decreases the efficiency of the heating, apart from the inefficient combustion which always begins to set in when any grate or burner is overloaded.

In the case of water-heating a temperature of 250deg. to 400deg. F., of the source, is very convenient for raising the water to boiling-point, but, once boiled, the temperature should be reduced to just over 212deg. F., so as to maintain the water at boiling-point without undue waste of heat or excessive evaporation of water. This is very easily and definitely effected electrically by the fitting of what is termed a "two heat" (or even a "three heat") element to the vessel. The water is boiled by raising the whole convector or enamelled strip to full temperature, and then kept at the boiling-point by switching out such a section of the heaters that the remainder will just emit the heat lost by radiation from the vessel.

Similar ranges are provided in room heaters, whether of the radiator or convector type, and in most cases one hour's operation at "full heat" will warm the room sufficiently to enable the temperature to be maintained at 60deg. to 70deg. F. for an indefinite period by the subsequent expenditure of "one-third full heat." This fact is *not* allowed for in Table X., although the gas, coal, and oil consumptions stated are the average values over the whole period of operation. Making this correction, the cost of electrical energy would be 24s. 6d. per 1000c.ft. heated per 1000 hours with B.T.U. at ¾d. or 32s. 6d. with B.T.U. at 1d.

This would considerably raise electrical heating in the economy classification already made on this basis; as a matter of fact, electric room-heating, even at 1d. per B.T.U., would then appear more expensive only than central slow-combustion stoves and charcoal stoves, both of which systems are subject to serious disadvantages in other respects. The above correction for the economy resulting from partial use at one-third full heat has only been applied to convectors, radiators still retaining their old position in the economy tabulation. The reason for this is that while convectors are fitted for long hours of operation in which the reduced heating may be employed, radiators are only used (in most cases) for intermittent work in which continuous operation at full heat during the whole period would therefore be probable. In estimating the revised fuel charges for the convectors for the 1000-hour operation on which the comparison is based, it is assumed that the convector is in use for 15 hours at a time, *e.g.*, in daily use from 7 a.m. till 10 p.m.

In Tables V. and VI. suitable heat-ranges for various types of heaters are given. As a mean of the ranges in actual use it will be found convenient to make the consumptions on the various "heats" have the following ratios :—

Radiators, 1 : 4 or 2 : 5 or 1 : 2 : 3.
Convectors, 1 : 3 or 1 : 3 : 5.
Kettles, &c., 1 : 5.
Water Boilers* 1 : 2 : 4.
Ovens 1 : 2 : 3 or 1 : 2 : 3 : 4.

If this be done much economy in working will be effected and the inflexibility urged against electricity by gas engineers will be found to be non-apparent; indeed, the provision of switches which will reduce the heating to a constant amount known to suffice for the object desired dispenses with much labour and results in economy of energy, besides obviating those wasteful "spurts" which have to be made with gas and coal when the heat has temporarily been reduced to too great an extent.

The fact that electric heating can at once be reduced in degree when the room temperature reaches the desired value, without the necessity of prolonged overheating such as results when a coal fire has been "made up" to raise the room temperature rapidly, is a further point of economy, and is, of course, one which is shared by gas-heating systems.

Volume and weight per unit effect.—Some indications of these figures of economy have been already given when discussing the efficiency of various types of heaters, and may now be referred to again.

Possibly apart from the charcoal stove, of very limited application, the electric radiator is undoubtedly the form of heater having both minimum volume and minimum weight per 1000c.ft. heated or per B.T.U. emitted, not even excepting the gas stove, which is, however, its closest competitor in this as in many other respects.

The weight of the electric stove increases but slightly with increase of heating capacity, the sole increase being that due to the extra lamp or convector strip fitted, as the case may be, and to the slightly increased weight of reflector or shield containing them. This increase is far less in proportion than the extra heating capacity gained, and even the largest electric radiators are easily portable. This, when compared with the weight of certain slow-combustion stoves whose weight increases from a minimum of, say, 100lb. to a maximum of one or even two tons in the largest sizes, is very striking. (The nominal heating capacity of the latter is, of course, enormous, but the weight per 1000c.ft. heated is still very high, being from two to ten times that of the corresponding electrical system.)

Taking here, as throughout, a standard room temperature of 60deg. F., the external temperature being 32deg. F., the figures of design shown in Table III. may be studied. (Too often in comparisons of this nature all reference to the temperatures at which it is made is omitted.) There is no object in working out the specific volume and weight coefficients for ovens and water-heaters, for in the case of the latter the volume is always determined by the volume of water to be heated, the volumes occupied by the electric convector on the one hand or the gas-ring on the other being nearly equal, and quite a small percentage of the total volume of the apparatus. A similar statement applies to ovens, but for these a different figure of economy has been already referred to (see Table XV.). This ratio of total overall volume to available volume forms a very representative criterion of the convenience and efficiency of the design apart from the thermal and monetary considerations which have already been dealt with.

The placing of various types of heating units presents well-defined rules, which are nevertheless often neglected, with consequent loss of efficiency. It is at once obvious that an ordinary coal fire placed directly at the foot of a duct, the chimney, up which a strong draught is necessarily and automatically maintained for and by the removal of the products of combustion, represents the most inefficient conditions conceivable. Not only are all air-currents into the room unwarmed until they leave via the chimney, but fully 80 per cent. of the heat generated by the combustion of the coal is at once carried up the chimney.

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* Of larger capacities than ordinary kettles.

This cause of inefficiency must be obvious to all, yet one frequently sees electric radiators and gas stoves placed in an ordinary fireplace without any attempt being made to close the base of the chimney. With the gas stove, a flue, with all its inefficiency, is still essential, but in the case of electric stoves this is no longer so, and where these heaters are used they should be placed rather at the *source* of all inlet air currents, so as to warm the latter before they mingle with the rest of the air in the room. Where stoves are placed in previously existing fireplaces every care must be taken to close *hermetically* the chimney opening. The great distinction between coal, and to a less extent gas, and electricity is that, while electric heaters can be placed at the *source* of air currents, the former must be placed at their efflux.

Where heaters are placed near walls, they should always be provided with reflectors at the back of them. In this respect heating units placed in the centre of the room or, at any rate, well clear of the walls present considerable advantages, and can be made to harmonise with most decorative schemes.

In very large rooms radiators, or preferably convectors, should be placed at about 12ft. intervals along the walls, and at 9ft. pitch perpendicular to the walls, the exact spacing being varied to make it symmetrical in each case. In this connection it may be noted that for large halls considerably less than 1 watt per cubic foot will suffice to maintain a suitable temperature (60deg. F.), particularly after the audience or congregation arrive.

Care must be taken when placing heaters near doors or windows that the heat developed is being carried *into* the room by the air currents, and not taken *out* by convection or radiation.

These statements apply alike to electric, steam, and water heating units, and to those gas and oil systems unprovided with flues; but where flues are required, as in the ordinary coal and gas systems, observance of these conditions is impossible: as a consequence considerable loss of efficiency follows. Of the merits of those fuel stoves for which flues are claimed to be unnecessary, and hence the stoves, like electric units, capable of use at any point desired, more is said later.

General Advantages, Risks, &c.—In this section it is proposed to discuss the particular conveniences and risks attached to each method of heating and the distinctive applications of each as influenced by the exact requirements, the locality, and the nature of surroundings, &c. Treating first the question of *convenience*, it is here that electrical apparatus assumes what is possibly its chief superiority (though, as shown elsewhere, it is by no means inferior in any respect). It affords a means of heating which is pre-eminently simple and clean. No ash, soot, smoke, or fumes of any sort are produced, and hence no "grate-cleaning" is necessary. No uptake or flue is required, and the whole heater is very light, so that it is easily portable from part to part of a room or to another room.

In connection with portability, however, it should be noted that many of the breakages of radiator lamp filaments are entirely due to carelessness when moving the apparatus. In these lamps a long loop of relatively heavy filament is only supported by its two ends. This arrangement is quite strong enough to withstand any fair usage, but its mechanical limitations should be remembered when moving the set. A few wall plugs placed round a room add greatly to the convenience of the electric system and cost but a nominal amount (see Table VII.).

An electric heater can be switched on to full heat in a moment, and though gas fires follow closely in this respect they cannot compete with electricity as regards the cleanliness and portability referred to above. After producing the required heating effect the radiator can be switched down to, say, $\frac{1}{4}$ heat to maintain this effect, and finally can at once be switched off when its services are no longer required. All these advantages are, of course, shared by gas stoves.

Coal, coke, and oil stoves are far behind electrical heaters in the respects of cleanliness, labour required for stoking, lighting, &c., and general convenience and safety. A coal fire has to be lit some time before the room or oven is required for use and continues to burn for some time after the need for it has ceased, the residue of fuel in the grate being wasted.

Electric heaters can be "lit" time after time with no additional labour or expense, and when in operation their effect is perfectly definite and no trouble due to the fire becoming "low" and so on can possibly arise. No attention is required for heat control or stoking, and any given temperature can be maintained for quite indefinite periods without the least attention.

Next to gas fires, oil stoves approach most nearly to electric stoves in convenience, the amount of attention required for heat regulation and fuel renewals being very small. Oil stoves are, however, expensive (see Tables IV. and XI.) both in first cost and operation, dangerous and messy.

The above points of convenience apply even more forcibly to cases of electric cooking, where the advantages of a perfectly definite operating temperature and absence of fumes and heating of the surrounding atmosphere are boons not to be despised. The latter aspect of this question is dealt with more fully in the Health Section.

Risks.—On this point again, electricity displays immense advantages. The greater risks with gas than with electrical apparatus have been examined fairly fully in the Lighting Section of this series, and hence need little further treatment. Owing to the more exposed but less visible nature of the flame in a gas stove there is, if anything, a greater risk of fire with this method of heating than with a coal fire. The risk of explosion is, of course, ever present, and is greater now that a larger escape path, via the burner, is available in case of accidental displacement of the gas-tap. Electric radiators, however, behave just like glow lamps in that if they are broken they are at once "burnt out" and all risks of fire so disposed of. In convectors there is no possibility of fire by breakage or otherwise; the maximum temperature of bare convector strips is 260deg. F. to 300deg. F.—quite insufficient to cause ignition of any material that could come in contact with them. Thus the fire risk is *nil* with electric heating, and this method may be employed with perfect safety in motor sheds, powder mills, &c., providing any of the many airtight switches now available be used to prevent danger due to sparks on opening or closing the circuit.

With coal or coke the well-known dangers of chimney fires, fires started by live coals falling or "cracking" out of the grate, and so on are too familiar to need repitition. Though the probability of these risks materialising may be minimised by the use of fire guards, by cleaning the chimney at frequent intervals, and by carefully excluding wood or other inflammable materials from within or from the neighbourhood of the flues, yet the risks undoubtedly exist to a very marked degree.

With oil stoves the usual risks due to a naked flame, protected only by a glass chimney, are present, and in addition there are the much greater risks consequent on the presence of a quantity of very inflammable fuel (which is, moreover, liquid) in the reservoir immediately below the flame. This oil is extremely liable to ignite or explode, whether in consequence of overheating of the stove or by overturning of the latter.

None of these risks attend the use of electricity.

Points affecting the decision as to which system should be installed in any given case are detailed in the next section, before passing on to which a few notes comparing the appearance of various heating apparatus may be given. This comparison is obviously difficult to make, since *any* heater can be made to have practically *any* appearance desired, but the features mentioned below concern the standard types of apparatus placed on the market.

The appearance of ordinary coal grates is too well known to need any particular comment; hence, passing on to charcoal stoves and slow-combustion stoves, it may be noted that these are, in general, of clumsy, "heavy" appearance and of little artistic value in the decoration of a room. Oil stoves may be, and are, made on more æsthetic lines. The fundamental burner and glass or mica shield is surrounded by an open metal-work structure, which may be of very pleasing appearance. Gas stoves might be made much more elegant than they usually are: the ordinary room stove is usually remarkable for its squat ugliness, while in gas-steam or gas-water radiators little attempt is made to relieve the clumsiness of their build. Electric radiators and convectors are undoubtedly the most artistic heating agents at present available. In this case artistic design is the rule instead of the exception. At the lowest prices very beautiful patterns are available, and the graceful curves and lightness of design are no doubt largely due to the extensive use of sheet copper and brass. The sheet metal being used and the whole being very light, the cost of material is relatively low. Owing to the absence of all flame and fire risk, radiator lamps and convector strips can be arranged so as to meet the requirements of artistic design.

With regard to steam and water heating, the unsightly appearance of pipe ranges running round a room and the remarkable facilities incidentally offered for the collection of dirt and dust behind them are well known to all.

The appearance of cooking ovens is not a very important matter, and hence need not be considered here, but it will at once be apparent that the electrical equipment has again the superiority.

Distinctive Applications of Various Systems.—Steam heating is only economically practicable in very large establishments where from 10,000c.ft. to 60,000c.ft. of space, at least, have to be heated.

This is owing to the very high initial cost of the apparatus required, and to the inefficiency of small equipments. The same remarks apply to water-heating systems, but where it is decided to install either steam or water heating, steam should be used, if possible, since the cost of installation is lower than for the water system. Practically the same boiler will suffice for a L.P. steam equipment as for a water system, while the pipes required may be of much smaller diameter in the former case (see also Table I.).

With steam heating, however, the pipe system must be very carefully planned, and must be lagged in all exposed parts, or the condensation losses will be serious or even dangerous. It will be shown in the Industrial Section that steam and water heating are very applicable to large workshops, and possibly then become more economical than electrical heating, but only owing to the relatively high price still pertaining to electrical energy, and not to any inherent limitation or inefficiency of the electric system.

For domestic use steam or water heating is not advisable, the only conceivable instance in which it might be reasonably adopted being that of a country residence placed near (uncomfortably near!) a range of hot-houses, from the boilers of which steam or water pipes, adequately lagged, could be run to the house. It is hardly necessary to point out that such a system would be very expensive and inefficient in operation. To make steam or hot-water systems economical, a supply of cheap coal is necessary in addition to the installation of large boilers.

Coal Grates.—This means of heating being at present universal with by far the greatest part of our population, any dissertation on *its particular applications* may appear superfluous.

The disadvantages of coal fires as compared with electric heaters are dealt with in other sections of this article. The economy of their use as regards fuel charges has been shown to be very slight, unless a phenomenally cheap coal supply be available; while, taking all costs into account, this economy is, even then, hardly existent (see Tables XI. and XIII.). Further, it is common experience that in the coal districts, where alone coal can be bought very cheaply, the quality of the fuel is bad, all the best being shipped to the various centres of demand.

Several cases in which coal fires are absolutely impossible on account of the danger of naked flames may be mentioned. Such are motor sheds, which nevertheless should be preserved at an equable temperature to keep lubricators, carburettors, &c., free, while in the subsequent Industrial Section we shall find powder mills, flour mills, oil warehouses, manufactories of very inflammable fabrics, celluloid, &c.

It is true that for domestic use coal fires need no energy supply such as is required by electricity or gas, and hence they are applicable in country districts where the latter is not available. On the other hand, it is becoming increasingly common to find electric supply (whether from private water or suction-gas-driven plant or from a co-operative village power-house) in districts where a gas supply would be quite impracticable from the constructional, operational, and financial points of view. In such cases particularly a heating load would be most conducive to economical supply.

Gas.—With this heating agent it is much easier to deal in the present comparison. The only advantages of gas over coal lie in the freedom from ash and soot, and in the superior convenience of rapid lighting to full heat. The fumes and dangers of naked flames are still present, and a risk of explosion is introduced previously non-existent. As compared with electrical supply, mains are necessary as in the latter, but the pipes, both main and distributional, are more expensive and clumsy to deal with. Electric heating obviates at once all naked flames and explosion or fire risk, while being quite free from soot, ash, and fumes of any kind. For this reason electric heating is applicable to every phase of domestic usage, and is especially valuable in hospitals and nurseries, &c.

Flueless Gas Heaters, for which it is claimed no flues are necessary and yet no danger to health from fumes exists, are movable, but are not so conveniently so as radiators, owing to their much greater weight and to the disadvantage of their requiring a flexible armoured tubing instead of a "twin" flexible wire. To the health aspect of these heaters recurrence is made later.

Gas heaters (like those burning coal or oil) must not be used in the neighbourhood of explosive or inflammable materials; steam, water, hot air, and electric stoves are alone applicable to such cases.

Oil Stoves present very few qualities likely to elevate them in the favour of users. They are only of real value in temporary bungalows, or for holiday trips, &c., or where coal supply is exceptionally dear or inaccessible. True, they avoid ash and soot, but the much-increased risk of fire, the "messiness" of oil, and the existence of smoke and fumes militate against their use. Probably oil heating would be adopted as a last resort where every other method proved impracticable. In such cases, however, the difficulty of oil transport must be remembered: oil cannot be regarded as the infallible ultimate solution of all difficulties regarding the provision of methods of heating.

Central Air Heaters are very economical of fuel as already shown, but their very high initial expense and trouble of installation bar them from very general use. For certain large installations, particularly in halls where a *very* moderate heat is required to be maintained for long periods, the system has some advantages. Unless provided with an elaborate system of ducts the heat distribution is liable to be very irregular.

The system is very healthy and capable of application to explosive neighbourhoods (at the cost of special stove isolation chambers), but in these features it presents no advantages over electric systems.

The distinctive applications of electricity have been set out—this form of heating is applicable to every case of domestic heating, and is inherently suitable wherever decorative effect, efficiency, freedom from dirt and smoke, and from risk of explosion are desired.

Electric radiators should be used in small rooms and where temporary use alone is required, whereas convectors should be used in the heating of a room continuously occupied; the principles governing the location of each are the same, and are as already stated.

For general use there is a great future before the combined radiator and convector in which one-third the total wattage (reckoned at 0.75 to 1.0 watt per cubic foot to be heated) is utilised in radiator lamps, behind or above which is placed a block of convector strips, in a suitable casing, utilising the remainder of the power supplied. In this way an exceedingly cheerful appearance is obtained, together with the radiant heat so appreciated from coal fires, and the convected heat which is so efficiently obtained from steam pipes, but in the evolution of which an ordinary fire quite fails (all the convected heat of a coal fire goes up the chimney).

Health Conditions—Indirect Costs.—These are practically the same as set out in such detail in the Lighting Section of this series, and hence need not be reiterated, except in so far as they are changed by the use of heating instead of lighting units, and in so far as the introduction of sources of energy not already dealt with (steam, hot water, coal, and oil) affects the comparison.

As before, electricity is immeasurably the most healthy of the means available, being even superior to the hot-air system, in that no dust can be carried into the room from air ducts, &c., where it inevitably collects after a time, its removal being both difficult and expensive. With electric heating the peculiarly musty smell attained by all air fed through pipes or ducts is avoided. The extreme unhealthiness of all flueless heaters will be appreciated from the analyses given in the Lighting Section, while from the remarks there made the superiority of electricity in all matters concerning health and indirect expenses will be apparent, especially when the higher consumption of fuel, and hence greater vitiation of atmosphere where coal, gas, and oil are concerned, is remembered.

Steam and hot-water pipes or radiators might be considered the *ne plus ultra* of healthy operation, but, as a matter of fact, unless the very greatest care be taken in the removal of dust and dirt from them, the very unpleasant smell of "burnt iron," really due to the heating and singeing of dust and fluff on the pipes, will be experienced. Anything more unhealthy or more unpleasant than this could not be imagined.

In conclusion, we may be permitted to apply our results to a conception of the future. To look ahead, the days are fast approaching—indeed, are distant but a moment in the eternity of time—when our coal-beds will be exhausted. With that exhaustion disappears the use of coal gas. Oil lakes probably exist still undiscovered, but they, too, will soon be drained. Yet electric power will remain. By water or wind power we shall still be able to obtain energy in a form convenient for heating, lighting, and power, and it is probably to that source of power, the tides—eternal so far as we know—that we must look for power when the sun has so far cooled as to cease regenerating our waterfalls for us.

Electrical energy, of superior economy, even in the zenith days of coal and gas, may—by the use of tidal energy ceasing only with the motion of our universe, and hence truly corresponding with the "end of the world"—be our salvation from the dark and cold that must otherwise settle on us and exterminate us when the sun becomes an earth.

R. E. NEALE.

ELECTRICITY IN FIELD WARFARE.

One of the most important lessons of the Russo-Japanese War was that the higher technics were not wasted upon military men. Throughout these tremendous operations the value of organised science was again and again brought to the front. To take one isolated example, it would have been impossible to maintain combined operations in a fighting front extending for miles, and working through country which was often of a very broken character, without the extensive use of flexible field telegraphs and telephones. How much of the results of the fighting was due to electricity in its several military applications it would, perhaps, be extremely difficult to say. It is, however, very certain that electrical engineers are obtaining a more and more important position in military work in the field.

It is not easy to distinguish absolutely between field and fortress work in relation to engineering. While fortress equipment offers many opportunities for ingenious and oftentimes large power applications of electricity, the chief function of the electrical engineer in the field appears to be the securing of mobility and swift action due to the time-saving properties of electricity. At the same time it must be remembered that field fighting can be rarely conducted in these modern times without entrenchments of some kind, so that the subjects of field and fortress equipment to some extent overlap.

Our own nation received some extremely useful lessons on the value of electrical engineering in military operations during the South African War, and not the least instructive, as well as a very thrilling, contribution to the proceedings of the Institution of Electrical Engineers is the lecture which Lieut.-Colonel R.E. Crompton, E.E. (R.E.) V., gave at the end of 1900 as the result of that enterprise. From that account we may summarise the sphere of the electrical engineers in field warfare as: the arc and incandescent lighting of working parties, depots, railway sidings, and the like; the reconstruction of telephone and telegraph lines and instruments destroyed by an enemy; the laying of temporary communications with flying columns and the various points of firing lines; the overhauling and equipment of electric block and gong systems on railways; the illumination of points subject to night attack; and the operation of searchlights for discovering the position of an enemy, signalling by flashes of light at night, and aiding the operations of friendly troops. In order to appreciate the way in which these operations were carried out by the Corps of Electrical Engineers (Volunteers), it is necessary to read the report of that lecture, and also to read between the few lines which the modesty of Colonel Crompton would permit him to write.

One of the first uses electricity possesses for the military engineer is, therefore, its application to the searchlight, and Figs. 1 and 2 illustrate the type of equipment supplied by Messrs. Crompton & Co., Ltd, which went out to South Africa. Although since that date the numerous improvements which have been introduced have left these obsolete, they are of interest as possessing the value of actual service. For military purposes 24in., and in some cases 30in. and even 36in., projectors are used in the latest designs of this firm for mounting on field-service equipments. The arc lamp is arranged for automatic or hand feeding, having horizontal carbons, the arc being kept steady in a central position by a

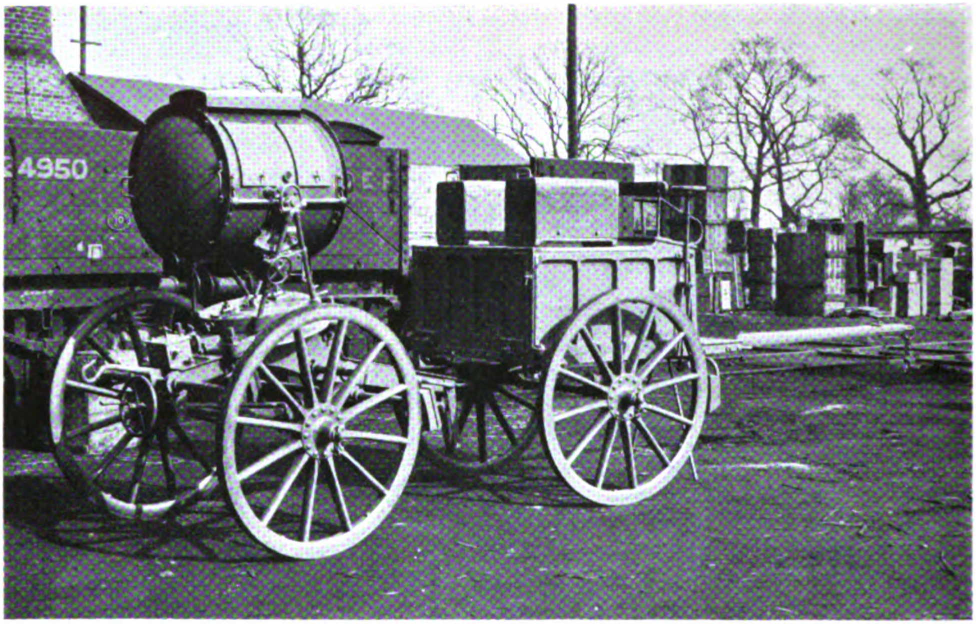

Fig. 1. Electric Projector and Cart as used in South African War.

suitably placed magnet. The projector cart as now constructed is self-contained, mounted on four wheels, and has accommodation for two men. The cart, which is drawn by four horses, carries a portable tower and projector, the latter two fittings being readily detachable from the cart. The cart is made as light as possible consistent with strength, and space is provided for the stowing of the projector spare parts and carbons in the cart. The telescopic tower carrying the table and projector is capable of extending these parts to a height varying from 20ft. to 40ft., and from the moment of halting to the placing of the projector in position at the top of the full extension of the tower the time taken is only a few minutes. During the period when the Pretoria and Delagoa Bay Railway was threatened by night attacks from a Boer commando, it was found necessary to install a searchlight at the top of the colliery shaft near Brugspuit Station, the dynamo being driven from the mine engine. In this case, as in many others, the advantages of height were fully realised, and the elevation of the projector has another incidental advantage, that, in case the fire of the enemy is drawn by the light, there is some chance of the projectiles passing over the heads of the men working the searchlight. The usual field equipment consists of a set of four carts, one being the projector cart above described, carrying the tower and projector with its spares; the engine cart mentioned below; a cable cart carrying the necessary cable to run between the generator and projector, and also a small drum for the controller cable; and one tank cart, or two if it is thought necessary, to provide petrol or spirit for the engine. The cable carts carrying the flexible connections from dynamo to searchlight are arranged so that the seats and all fittings can be removed as soon as a halt is made, thus enabling the cable to be readily run off the drums. Plug connections are mounted on the cable barrel, the loose end of the cable being taken to the projector. The flexible connections are taken from the generator cart, so that no loose ends hang about.

One of the great problems connected with

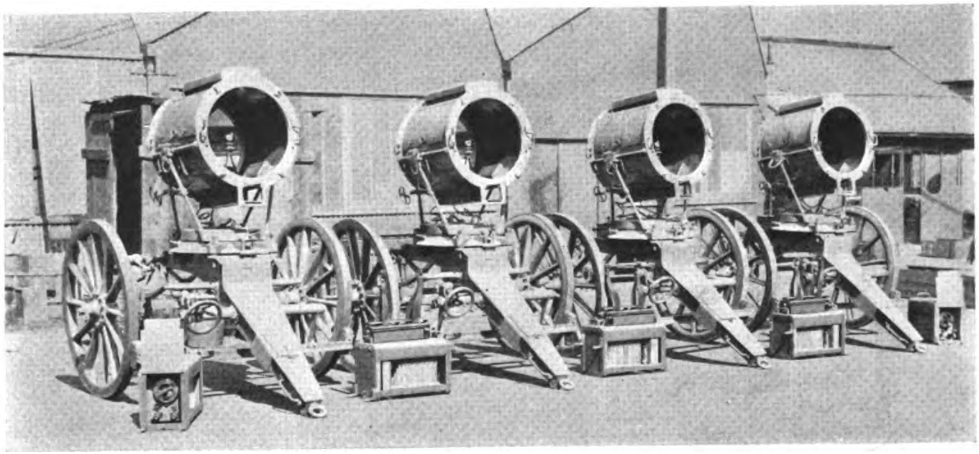

FIG. 2. GROUP OF 24IN. PROJECTORS.

electricity supply in the field is the transport of fuel to work the electric equipment. As the result of service conditions, however, there is no doubt that oil or petrol is the most universally adaptable agent of heat, failing the presence of a boiler which will accommodate itself to anything from wood palings to dried grass. Moreover, in many situations water is unobtainable. For this reason the latest type of generator cart is fitted with a dynamo directly driven from an oil or petrol engine, the cart being arranged to be drawn by four horses, and provision being made therein for tools of every description. As an adjunct to the generator cart is the fuel cart, which is a simple arrangement with safety draw-off and filling arrangements. Its size is dependent on the radius of action

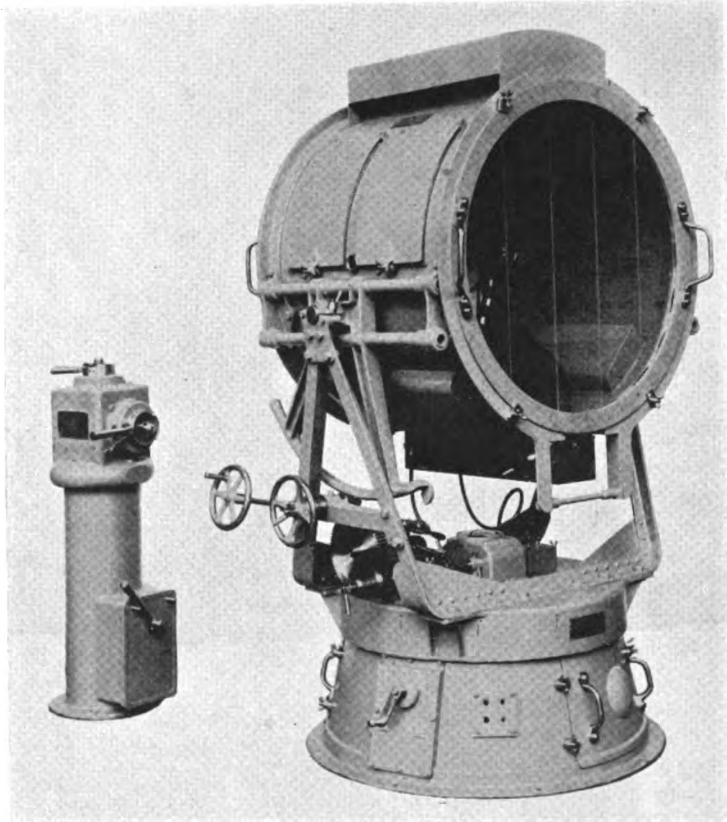

FIG. 3. 36IN. PROJECTOR WITH ELECTRICAL CONTROLLER.

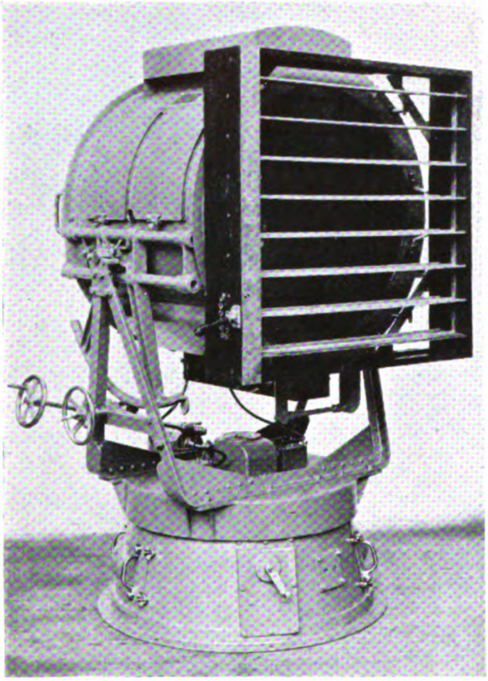

FIG. 4. 36IN. PROJECTOR WITH FLASHING SHUTTER. HAND-CONTROLLED.

required, and in some equipments it is divided into several units. The latest system of control gear consists of a small controller of exceedingly light construction and fitted with straps so that it can be strapped to a man's body. From this controller a light cable, which can be made to a length of, say, 200 yards long if necessary, passes up from this to the projector. The controller itself is worked by one handle in order to allow the operator to use one hand for discerning the enemy or object of fire at a distance, while with the other he can control the projector with the one handle so as to give it movement in either the horizontal or vertical planes at various speeds.

With regard to the searchlights or projectors themselves, Figs. 3 and 4 show typical projectors. The whole head is mounted on a circular ball-bearing race, so that, if necessary, it may be swung round in searching operations with the utmost swiftness. In addition to this, slow-motion hand-control gear is usually fitted to the projector, consisting of a hand wheel working on a worm, enabling the light to be swept slowly round in a horizontal plane with great steadiness in order to search the ground thoroughly. Another hand wheel working on a vertical sector gives control to the vertical movements of the beam, so that the utmost flexibility and precision are obtained through a range of about 30deg. above and 30deg. below the horizontal position. This hand control is fitted with quick throw-out devices, which, when thrown out automatically, bring the gear into action ready for electrical control, this being nowadays largely adopted.

Mention was made above of the liability of the searchlight to draw the enemy's fire, and to overcome the troubles attendant on this feature, as well as to give the operators a very much better chance of discerning their objects when standing at a distance from the projector itself, Messrs. Crompton & Co., Ltd., fit their latest type projectors with an electrically operated remote control which is auxiliary to, but does not interfere with, hand operation. Fig. 3 shows this gear, which consists of a motor-operated turn-table and an electric drive on to the vertical sector. The motors, which are waterproof, are concealed in the base of the projector and drive the gearing through slip clutches, so that there is no fear of overwinding. Both these motions are controlled by a rheostat and controller gear mounted in the upright standard shown to the left and in the rear of the projector, but later field-service patterns include the lighter form of controller mentioned, consisting of a controller capable of being strapped to the body. In the type shown in Fig. 3, which is probably more useful for coastal defence than for field work, the controller can be mounted in any convenient position under cover, wires being run from it to the projector. The handles are so arranged that the movement of the vertical handle produces vertical movement of the beam, while the movement of the horizontal handle produces a horizontal displacement of the light. The principle is essentially the same as in some of the modern electric jib-crane controlling equipments, and is far superior to the older method of attaching an arch-piece to the horizontal movement operated by a cross head and guide ropes from the covered entrenchments.

Passing reference was made above to the use of electricity for signalling purposes. In lands such as India and Egypt, where continuous sunshine may for a long period of the year be relied upon, our forces have been accustomed to the use of the heliograph for transmitting messages either on the Morse code or by private signals. Where sunshine is intermittent and over distances too great for flag signalling, and principally at night, the electric projector is extremely useful for this purpose. As a matter of fact, searchlight projectors are now being used very largely by naval departments for day signalling by battleships and cruisers, the results obtained being highly satisfactory, as the beam and flash from the searchlight at a great distance can be seen and signals taken when a ship is at such a distance that it is almost invisible in the daytime. When used in signalling operations it is fitted with a series of parallel vanes or slats capable of turning on their long axes, and mounted in a frame. These are lever-connected to a hand-operated handle, so that they are opened and closed in a similar manner to the "swell" shutters of a church organ. Fig. 4 shows a 36in. projector fitted in this manner, and it is evident that when the shutters are edge on to the beam, this is able to pass out with practically undiminished strength. A revolution through 90deg. of the shutters, however, totally obscures the light. It will be remembered that during the siege of Ladysmith the first communication between the beleaguered garrison and the relieving columns was effected by means of searchlight signalling.

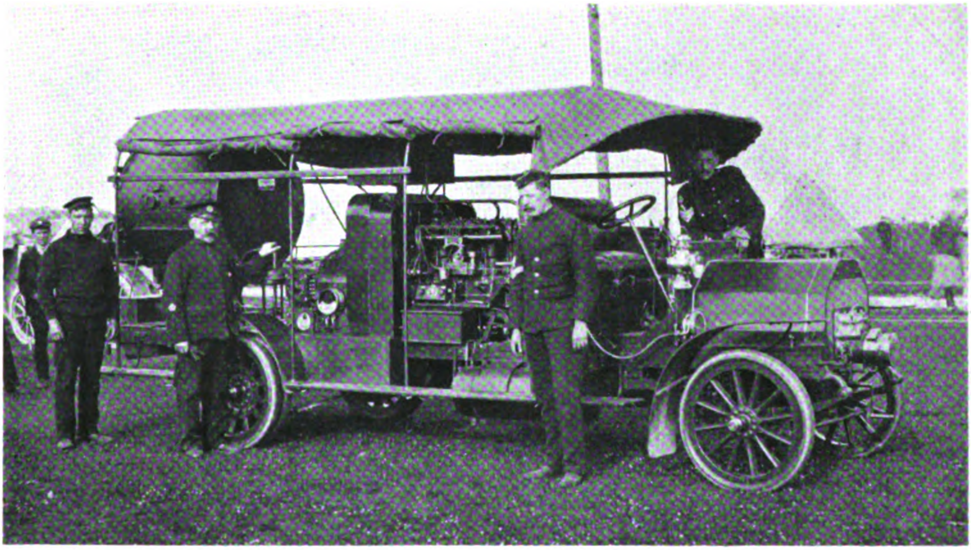

FIG. 5. MODERN SELF-CONTAINED ELECTRIC SEARCHLIGHT EQUIPMENT ON MOTOR CAR.

One of the latest developments of the modern military searchlight equipment for operations in the field is shown in Fig. 5, which represents an automobile searchlight apparatus belonging to the No. 1 Tyne Division of the Royal Engineers (Volunteers), and which is one of the most recent additions to the engineering equipment of the British

Army. It will be seen that the searchlight, which is of 4000c.p. beam, is mounted on an extension of a medium-speed motor-car, driven by a four-cylinder 45b.h.p. petrol motor, driving the tractor by means of a chain and sprocket wheel attached to the rear road wheels. It is constructed to run up to twelve miles an hour on smooth roads, but is furnished with very heavy rubber tyres, enabling it to negotiate roads which have been cut up by the passage of troops and artillery, and even to run over ploughed fields at a slower speed. The fuel is carried in cylinders low down in the car, and taken to the carburettor of the searchlight motor by a small force pump. Immediately behind the engine in the illustration will be seen the radiator, and behind that again the measuring and control instruments for the searchlight. When travelling from one point to another the diverging lens of the projector is carried in a position immediately behind these instruments, and when the projector is put into operation the lens is taken from this position and mounted on the front of the searchlight at the rear of the car. In order to operate the equipment two men are required, but the car is capable of carrying four extra men if necessary. The whole arrangement forms a remarkably compact and portable equipment, of which much may be expected in time of war.

A considerable amount of the work of the electrical engineer contingent attached to an army is the turning of night into day for the furtherance of constructional engineering operations upon which the movements of an army depend. An enemy in retreat, for example, makes a point of blowing up railway bridges, exploding dynamite cartridges under the permanent way, and breaking up any power-producing plant which may eventually be turned to use against them. Quoting once again from Colonel Crompton's lecture, we may recall the fact that during the advance of the railroad from Bethulie to the Vaal arc lamps were worked nineteen nights, and, assuming that one night's work is equal to two-thirds of a day's work, the advance of the railroad was hastened by not less than twelve days, the money value of this alone to the nation repaying many times over the entire cost of equipping and sending out the electrical engineers. Difficulties are often experienced in obtaining the necessary source of power for such lighting operations, and

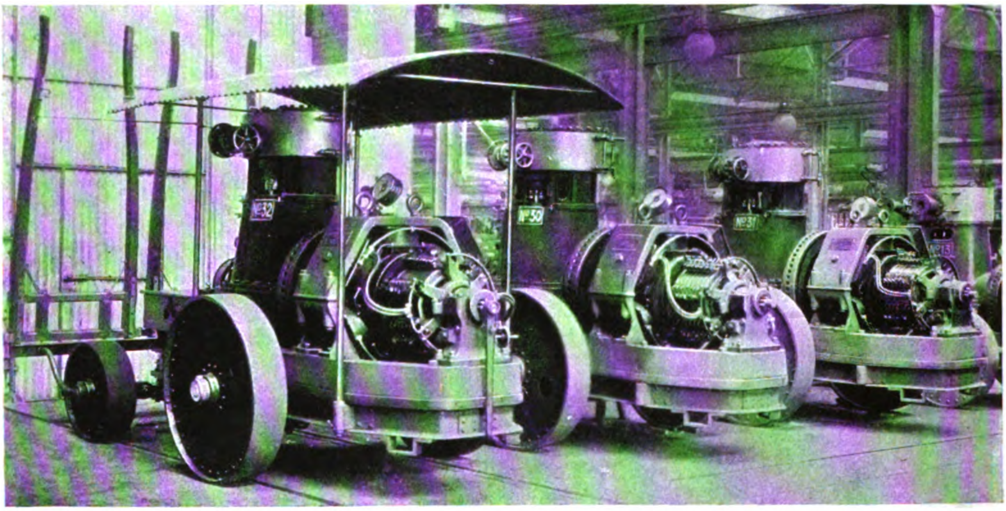

Fig. 6. Group of Portable Steam-electric Generating Plants.

engineers have since been busy in perfecting small transportable units capable of being rigged up wherever desired, in place of wrecked machinery, for lighting places such as railway depots, hospitals, and attack points. As an example of the type of portable plant which may be considered suitable for use in this way where steam is available may be mentioned the group of enclosed two-crank forced-lubrication engines and direct-coupled dynamos designed by Messrs. W. H. Allen & Co., Ltd., of Bedford, to the order of the Government for use in dockyards, and shown in Fig. 6. The necessary requirements met in this design are strength, compactness, and as much enclosure as possible. They are each drawn by four horses, and are completely ready for coupling up to an available source of steam power. The dynamos, which give an output of 105 volts, 660amp., at 400r.p.m., are of the six-pole compound-wound type, and each set is mounted on a substantial wagon with a corrugated-iron roof. The sets are provided with waterproof curtains hung from the roof, which protect the plant from weather and can be drawn aside when required. The weakness of steam sets for military purposes, even in depot work, is that boilers of the required pressure are not always available, and even then fuel cannot always be found. Petrol, on the other hand, has the disadvantage that, in our own country at any rate, no natural source is obtainable, and we should be compelled to rely on storage or on supply by sea.

The important subject of telegraphy and telephony has not yet been dealt with, and we here find a considerably wider scope than the limits of this article will allow. Attached to every division of infantry brigades during operations in the field is a telegraphic corps whose duties are to erect, in either a temporary or permanent manner, telegraphic lines and to work the instruments. They have also frequently to repair the damage done to trunk lines, railway telegraph and railway signalling systems, and to take charge of these in the interests of the military authorities. Incidentally they have gently but firmly to resist the strenuous efforts of the war correspondent to get his dispatches through before those of the Commander-in-Chief. The cable detachments of a telegraphic corps are sometimes required to work right up to the headquarters of an infantry brigade during action, and this not infrequently includes not only a considerable amount of personal danger, but a very great likelihood that communication may very shortly be again interrupted. This service therefore calls for a combination of personal bravery and technical knowledge which is somewhat exacting. The necessity for electric intercommunication does not, however, end with tapping the headquarters. Communication by "flagging" puts the signallers into exposed positions, and over long routes is tedious. Moreover, the messages can very possibly be read by the enemy, and the same applies alike to lamp signalling, heliography, and even searchlight flashing. In this connection the field telephone is receiving a degree of attention from military authorities which is the more marked because the Japanese in Manchuria made such use of the telephone. Its use involves no special training in signalling; the wires may be run across a zone exposed to a hot fire, it is the ideal medium for exchanging messages at great speed; and, above all, it possesses secrecy. Situations and positions are not revealed to the enemy, and there is very little likelihood of information being tapped by hostile troops. The value of the field telephone was realised during the South African War, Lord Kitchener's staff having attached to it two of the Electrical Engineers (Volunteers) to use their bicycles and field telephones as required at the front. The bicycles were provided with reels on which bare copper wire of small diameter was coiled, suspended at the back of the saddle so that, as the sapper rode, he laid down the line.

One of the latest applications of the field telephone is the apparatus illustrated in Figs. 7 and 8, which show the Medhurst

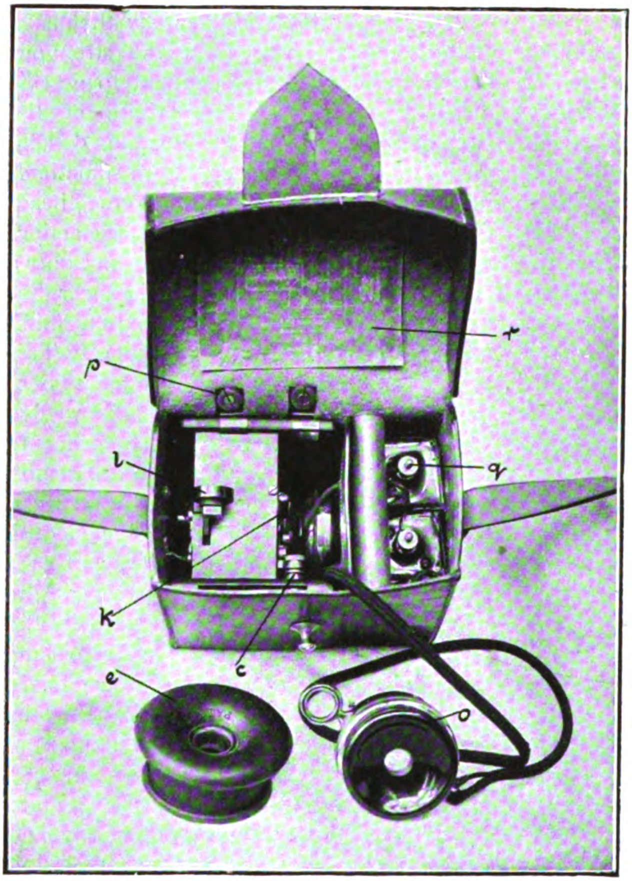

FIG. 7. MEDHURST PORTABLE TELEPHONE EQUIPMENT.

portable telephone and telegraph instrument made by the International Electric Company. The whole outfit weighs only a little over 4lb., and the number of accessories is reduced to a minimum. It consists of a transmitter of the sealed capsule microphone type, hermetically sealed and impervious to moisture; a receiver of a double-pole watch pattern with an adjustable clamped diaphragm, and fitted with a telaupad; and a telegraph Morse key which is depressed while speaking, and which can also be used in conjunction with a switch and buzzer for telegraphic messages. This buzzer consists of a coil and armature constructed so that two dry cells giving 3 volts are enough to allow communication over long distances with a margin of battery power. The high e.m.f. and frequency produced in the buzzer cause the receiving telephone to sound, even when, owing to defective lines or even a broken circuit, speaking has become impossible. The cable used is generally single wire with earth return, as twin wire doubles the weight and is liable to kink and short circuit. Stranded wire weighing from 20lb. to 25lb. per mile is used, and a cable drum, seen in Fig. 8, carries about 550 yards of light field cable of this description. It is, of course, well insulated, but use may be made in emergencies of ordinary fencing wire for opening up communication between outposts. The chief uses of the field telephone may be summarised as being between bodies of troops in the early stages of an attack in an outpost line; between headquarters and battalion and the firing line, and between infantry brigadiers and their divisional and battalion commanders; between the officers commanding artillery and the units under his command, and between batteries and their observing stations. Ammunition columns have also to be kept in touch with the artillery they are serving, and one of the latest applications is for transmission of messages from observing officials in captive balloons to headquarters. It is invaluable for cavalry, enabling them to tap wires or to utilise existing wires by means of phonic buzzing, thus transmitting information to the rear. It will be seen, therefore, that the field telephone is a most important adjunct to modern warfare.

It is impossible to more than briefly summarise the part taken by electricity in modern military life in the field, or to make more than a general reference to future possibilities. There is no doubt that wireless transmission of messages, both by telegraph and telephone, will be a prominent factor in any future fighting. Major Edgar Russell, of the United States Signal Corps, has already conducted experiments in this direction whereby messages were received by a balloon one to five thousand feet high from a transmitting station twenty-five miles away, and the chief difficulty at present seems to be the transmission of messages by electric discharges so near to a volume of gas. A considerably more deadly development may be the use of high-tension electricity in connection with wire entanglements. Such devices were used at Port Arthur, and had apparently a particularly ghastly effect. Whether this means of extermination will be ranked with the "dum-dum" remains to be seen. And perhaps in a kindlier way electricity may play its part in the theatre of war in rendering the task of the surgeon more easy. Dr. Behr, an eminent surgeon, has recently introduced an electric surgical knife which will, it is hoped, have a great effect in rendering operations both bloodless and rapid. It is not so much the shock of pain as loss of blood that renders a good many military surgical operations nugatory, and electricity, by coagulating the blood, limits hæmorrhage. Whatever the ultimate uses of electricity in this sphere may be, it is evident even now that should Great Britain ever again have the misfortune to be compelled to resort to arms, electrical engineers will be required, both in the field, to utilise their special knowledge, and at home, to see that the best appliances are manufactured and supplied to our Army.

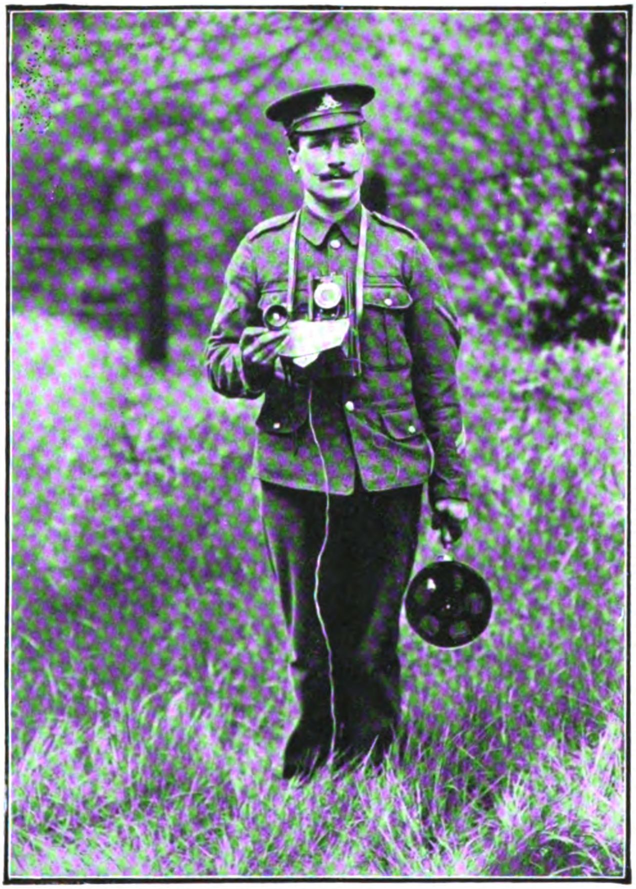

FIG. 8. MEDHURST PORTABLE TELEPHONE IN USE.

J. A. SEAGER.

THE DEVELOPMENT AND CONSTRUCTION OF THE ELECTRIC PIANO PLAYER.*

THE wonderful results obtained by the great masters of the art of piano playing ordinarily serve to disguise from us the simplicity of the means employed. This mechanical simplicity at an early date directed the attention of mechanicians towards seeking a substitute for the pianist's fingers. When a piano key is struck its hammer is thrown against the corresponding string, from which it immediately rebounds part way, and in this intermediate position it is caught and held until the key is released. The depression of the key simultaneously lifts the damper from the string. Both hammer and damper are therefore clear of the string while it is sounding. Nothing can be done to the key before the hammer is thrown, or after it is thrown and before the damper is returned, that can at all alter the tone produced. In any given instrument the pianist controls manually only the velocity with which the hammer strikes the string, and the return of the damper. The ordinary pedals add no new feature; they merely add to the ease of control. The wonderful art of piano playing is therefore built up by varying two simple elements.

Froment appears to have attacked the problem as early as 1850, but the author has not been able to obtain any accurate account of this work. In 1861 a patent for an electric player was taken out in Würtemberg by Andre. In 1867 the celebrated mechanician Hipp exhibited an electrically operated piano which is worthy of some attention. It may be considered as the foundation of the work of the present day, and, indeed, in some respects it is in advance of much of the subsequent work. The Hipp apparatus consisted of two parts, a transmitter and a receiver. The latter consisted of a series of electro-magnets with armatures pivoted so as to swing towards and across the poles, and having the armatures connected by wooden rods with the jacks of the piano action. The transmitter employed a roll of perforated cardboard or cloth, similar apparently to the music rolls now so familiar, which was drawn by means of clockwork from one wooden roller to another. On its course it passed over a metallic roller and under a comb consisting of wires properly spaced and held in an insulating frame. The roller and the wires of the comb formed terminals of electric circuits including the magnets in the piano. The method of action is obvious. It is necessary to add that expression was controlled by the insertion of resistances in the common return. That he chose a type of magnet whose action could be modified in this manner is one of the evidences of Hipp's knowledge and careful work.

Another Swiss, Spiess, exhibited an electric player in Paris in the following year, 1868. So far as the description goes, this player seems to be substantially the same as Hipp's. We are more fortunate, however, in that we possess a contemporary statement as to the results obtained. The clearness and distinctness in rapid passages are the subject of special praise. It may be of interest to add that Hipp operated with ten Bunsen cells and Spiess with thirty-six Daniell cells. To a considerable extent Hipp and Spiess must be regarded as being too far in advance of their time. The lack of a cheap supply of electric energy and the relatively small number of pianos in use would have precluded commercial success in any event.

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* Paper read by John F. Kelly, Ph.D., at a meeting of the Franklin Institute (U.S.A.), November, 1908.

At much about the same time as Hipp and Spiess, Prof. J. B. Webb and Mr. Oberlin Smith were at work on the problem in America. They sought to replace the perforated tape by one having the notes printed in metallic ink, and they tried also a conducting tape with the notes printed in insulating ink. Other work proved more attractive to both inventors, and they abandoned the piano player in an unfinished condition.

In the late seventies and early eighties William F. and Henry Schmoele of Philadelphia took out a number of patents relating to piano players. One of the patents described a music roll with the notes printed in metallic ink. The Schmoeles, who had on the whole a very clear idea of what a piano player ought to do, seem to have been deterred from the use of a straight electric action by the cost and unreliability of the supply of electricity at that time. They fell back on an electro-pneumatic action similar to that employed in playing organs from a distance, or, to compare their apparatus with what has now become more familiar, it resembled the present-day pneumatic action with the primary pneumatic replaced by an electric action.

At the Electrical Exposition of 1881 in Paris, Carpentier, the well-known instrument maker, exhibited a piano-playing apparatus which he called a repeating Melograph. The name Melograph had already been applied to an instrument exhibited in Vienna in 1873 designed to record piano playing. The complete Carpentier instrument was intended to cut a record of a composition played at the keyboard in the ordinary manner, and then to use this record as the music roll in the reproducer. In reproduction, which alone concerns us, Carpentier introduced a new idea. A shaft revolving at a fixed speed was placed under the keyboard. A number of brake shoes, corresponding to the keys to be operated and linked to them, were placed contiguous to the shaft, and pivoted so that a slight motion would apply them to it. When so applied the friction developed would pull down the piano keys with a force dependent on the speed of the shaft. The magnets controlled by the music roll, instead of operating the piano action, had only to throw the brake shoes against the rotating shaft. In this way it became possible to use smaller magnets and to economise in the use of electric energy, but unfortunately at the cost of losing control of expression.

Some dozen or more years later Carpentier's scheme was taken up by an American inventor, Mr. G. H. Davis, and embodied in a commercial machine. In the machine as now constructed Carpentier's cylindrical shaft has been replaced by one in the shape of the frustum of a cone with small apical angle. The chief improvement, however, is the addition of a hinged, three-piece, soft-pedal bar, controlled by three levers. By means of this, expression may be imparted manually to music which, as controlled by the music sheet alone, would be perfectly flat.

Most inventors, however, have preferred to follow in the line marked out by Hipp. It has been shown that Hipp inserted resistance in the circuit with a view to varying the strength of the magnets, and so the intensity of the blow of the hammers. Although Du Moncel described Hipp as obtaining in this manner a satisfactory range from *forte* to *piano*, a little consideration will disclose an essential weakness in the scheme : any given resistance introduced into the main circuit will have an effect the greater the more magnets in circuit, a very undesirable result. Yet it was not until some thirty years later that it was shown that the true method is to insert a separate resistance in each branch circuit. Before condemning too severely the electrical inventors occupied with piano players for their slowness in discovering this point, it might be well to take into consideration that an analogous fault still exists in some of the pneumatic players of to-day.

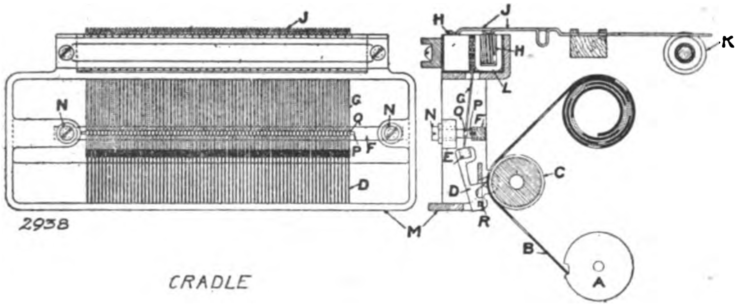


FIG. 1.

A, music-tape case; *B*, music tape; *C*, tracker roll; *D*, reading finger; *E*, ivory insulating block; *F*, contact bar; *G*, contact wire; *H*, resistance coil; *J*, comb wire; *K*, terminal; *L*, resistance coil frame; *M*, cradle casting; *N*, adjusting screws for contact bar; *P*, platinum strip and contact bar; *Q*, platinum bands on contact wires; *R*, swivel rod for reading fingers.

In order, however, that insertion of resistance may give effective control of the magnetic pull, and hence of the touch on the piano keys, it is necessary that the magnets should be peculiarly constructed. It is necessary that the attractive force should be near its maximum when the armature first begins to pull on the piano action. When a magnet is employed in which the attraction on the armature rapidly increases as the armature moves towards the poles, it is practically impossible to control the movement by the control of the current. In such a case the current that is required to start the armature from its initial position suffices for a violent blow at the end of the path. Hipp perceived this, but it was overlooked by many of his successors.

Those who have had experience with pneumatic players know that one of the most serious difficulties with such instruments is the susceptibility of the paper music roll to atmospheric conditions. Naturally the same trouble is encountered when a paper roll is used in an electric player, and there are some new troubles. The fact that the paper is pulled between a wire comb and a rotating cylinder, instead of being drawn over a smooth tracker board, does not make for better tracking. And again, if the electric pressure be high, there is a tendency to burn the paper where it acts as a circuit breaker; while if it be low there may easily be uncertainty as to contacts.

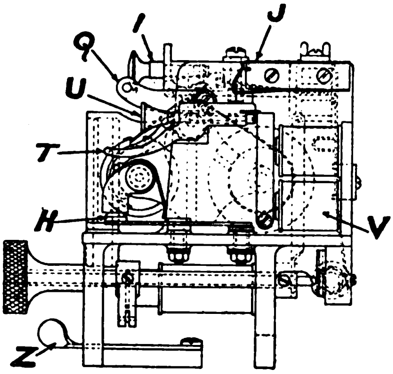
In a series of patents running from 1901 to 1904 T. B. Powers, partly in collaboration with M. R. Jewell, has shown a player combination designed to overcome these difficulties. Powers's direct contributions are more important than those of any of his American predecessors, and he has also shown great talent in his utilisation of the elements he took over from the prior act. His most important improvements are the substitution of thin metal tape for paper in the music roll, and the introduction of individual resistance coils in the branch circuits.

In 1905 the author acquired the Powers patents and organised the Telelectric Company to manufacture a player in accordance with them. Naturally in the course of manufacture many improvements in detail have been introduced, and some of great importance. It would be useless and wearisome to point all these out, but it will be of interest to describe the players now made, directing particular attention only to such changes as materially modify the musical results.

The apparatus in general plan recalls that of Hipp. The use of a metallic instead of a non-conducting roll has necessarily led, however, to a material change in the construction of the comb. In this instrument each of the elements of the comb consists of two parts—a reading finger proper, and insulated from this a wire acting as a contact maker. The contact is made with a separate contact bar instead of with the tracker roll, as in the Hipp apparatus. These elements, and a corresponding set of small resistance coils, are, in the standard sixty-five-note apparatus, set in a special frame, which, from its being pivoted in front to allow of a rocking motion, is usually called the cradle.

The cradle is shown in Fig. 1, and its relation to the rest of the machine in the general view Fig. 2. In Fig. 3 the construction and relation of the reading finger *D*, with its contact wire *G*, to the contact bar *F* and the resistance coil *H* are clearly indicated. The ivory block *E* serves to insulate the reading finger from the wire. It will be clear also from this figure that the metal music tape *B*, when unperforated, will lift the reading finger *D*, and so break the connection between the contact wire and the bar *F*. The wire *J* is one of a set forming a second comb serving to maintain connection between the resistance coils and the cable terminal *K*. When the cradle is rocked upwards the resistance coil is raised, and, as an inspection of the figure will show, resistance is introduced into each circuit. This rocking of the cradle may be effected either automatically by means of the magnets shown at *K*, *L*, and *M* in Fig. 2, or manually by means of the handle shown at *N* in the same figure.

The winding and unwinding of the tape constituting the music roll are accomplished by means of an electric motor *R* provided with a governor *S*, Fig. 2. The transmission from the motor to the winding and rewinding rolls is through a pair of rubber belts and a set of gear wheels. The lifting of the tracker roller into place by means of the lever *T*, Fig. 2, puts the winding gear in mesh, while the lowering of the same roller shifts to the rewinding gear. This shift may be effected by pressing the button *U*, but ordinarily it is effected automatically at the end of the selection by means of the trip magnet *V*, Fig. 2. At the end of the music tape an opening is cut which allows a special reading finger to close the circuit of this trip magnet, thus dropping the tracker roller and shifting the gear.



With this instrument a governor must be provided. Not only must this maintain a steady speed, but it must maintain steady any speed the operator may choose. The simple make-and-break ball governor shown in Fig. 4 accomplishes this remarkably well. The speed is varied by shifting the position of the contact arm *A* by means

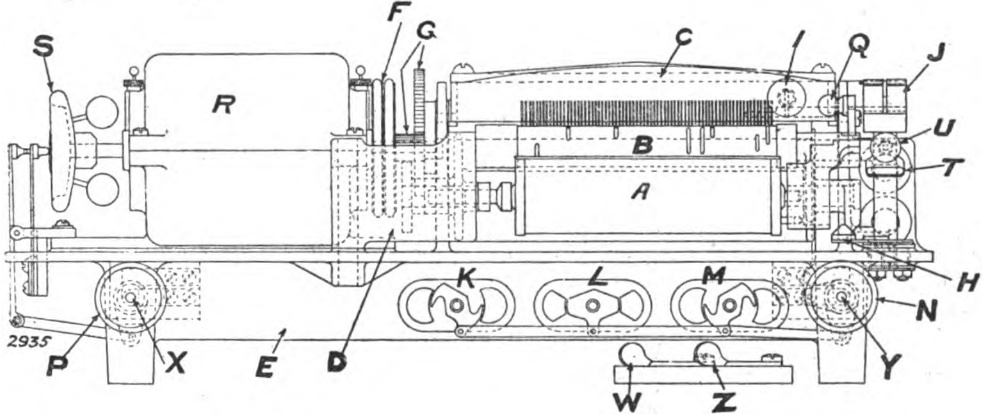


FIG. 2.

A, music-tape case; *B*, music tape; *C*, cradle; *D*, swinging carriage; *E*, base; *F*, rubber belt drive; *G*, gears; *H*, starting switch; *I*, expression cut-out knob; *J*, trip switch; *K*, forte expression magnet; *L*, medium forte expression magnet; *M*, piano expression magnet; *N*, expression handle; *P*, tempo handle; *Q*, carriage latch; *R*, motor; *S*, governor; *T*, lifting lever; *U*, trip button; *V*, trip magnet; *W*, base subduing switch; *X*, sustaining pedal button; *Y*, soft pedal button; *Z*, treble subduing switch.

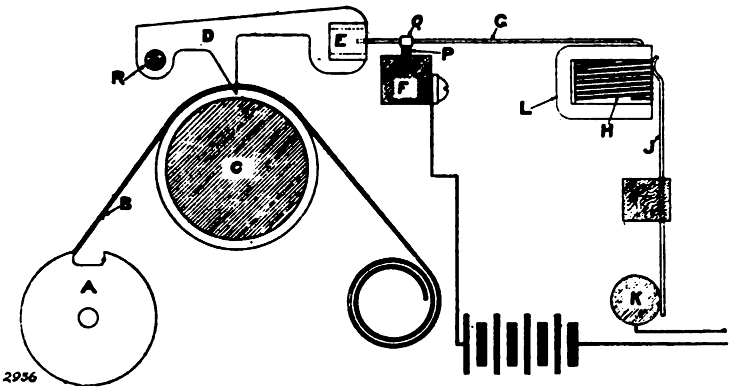


FIG. 3.

A, music-tape case; *B*, music tape; *C*, tracker roll; D, reading finger; *E*, ivory insulating block; *F*, contact bar; *G*, contact wire; *H*, resistance wire; *J*, comb wire; *K*, terminal; *L*, resistance coil frame; *P*, platinum strip in contact bar; *Q*, platinum band on contact wire; *R*, swivel rod for reading finger.

of the handle *P*, Fig. 4. This simple and absolute control is of special value in accompaniments. Because of it, it becomes easy for any singer to accompany himself.

Fig. 5 shows two views of one of the actuating magnets and the means of attaching the armature to the piano key. It will be observed that the rotary armature is so shaped and set with reference to the poles as to ensure a strong initial attraction, which, as before pointed out, is necessary in order that the touch on the piano keys may be effectively controlled by varying the current in the magnet winding. A small screw eye is put into the key, the connection between this and the armature being made by means of a flexible steel wire. The eye of the screw carries a small rubber cushion to prevent any clicking from being developed by the wire striking against the screw. It will be observed that this method of connecting leaves the keys entirely free at all times, so that, for instance, one may play a duet with the electric apparatus as a partner.

Magnets similar to the key magnets, but larger, are used for operating the pedal bars. These magnets are controlled by perforations made at suitable points in the music tape, or they may be operated at will by the buttons *X* and *Y*, shown at the centres of the handles *P* and *N* in Fig. 2.

The music tape is a brass ribbon 5in. wide and $\frac{3}{1000}$in. thick. The perforations for the notes are arranged in a similar manner to those on the paper rolls, but on a much smaller scale. The brass is only one-third as long as the paper for the same music. That the same proportion is not exactly preserved in width is due to the fact that the brass tapes carry other perforations than those corresponding to the notes. Perforations, as stated already, are provided for controlling the action of the pedals, for varying the resistance in the circuit, and for shifting to the rewinding gear at the end of the selection.

The cutting of each selection is so arranged that the *tempo* of any selection will be normal for a fixed motor speed. This applies even to what may be called the normal variations from the standard *tempo* of the

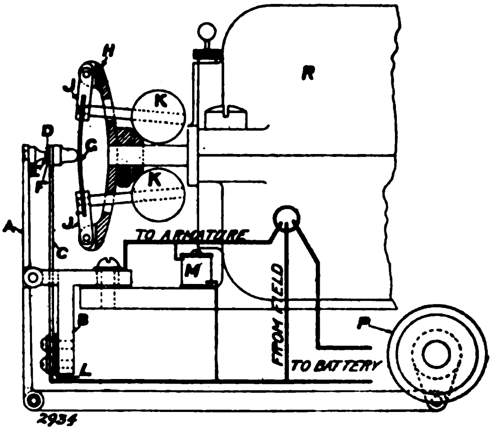


FIG. 4.

A, contact arm; *B*, governor bracket; *C*, follow spring; *D*, point of break; *E*, platinum point on contact arm; *F*, platinum point on follow spring; *G*, governor spring; *H*, governor disc; *J*, hinges for governor spring; *K*, governor balls; *L*, insulation block; *M*, shunt coil; *P*, tempo handle *R*, motor.

selection. Such variations are incorporated in the cutting. Variations in *tempo* to suit special tastes may be readily introduced by turning the handle *P*, Fig. 2, right or left, as may be required.

Apart from the variation in *tempo*, the means of obtaining expression so far described consist in the variable touch on the piano keys obtained by the use of variable resistance and the use of the pedals.

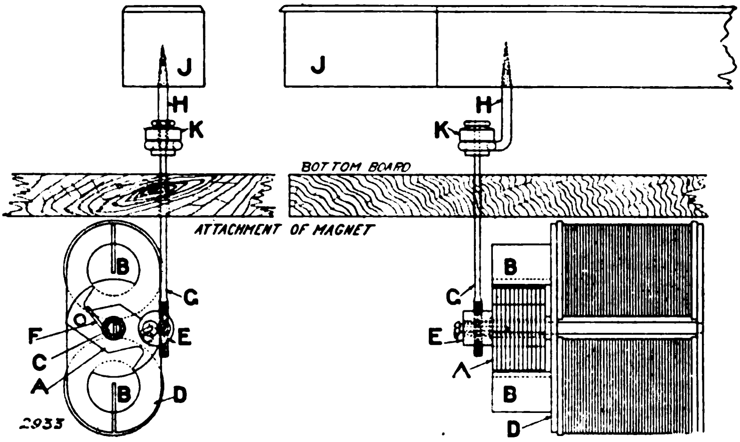


Fig. 5.

A, armature ; *B*, poles ; *C*, armature shaft ; *D*, brass yoke ; *E*, swivel ; *F*, armature return spring ; *G*, pull-down wire ; *H*, screw eye ; *J*, piano key ; *K*, rubber buffer.

It will be evident from this description, therefore, that two distinct purposes have been kept in view in the building of the Telelectric player. On the one hand the attempt has been to build a machine which, when left to itself, will reproduce with perfect accuracy the music as written by the composer and with the proper interpretation. From this standpoint the music rolls are cut, carefully avoiding all "adaptations" to make it easier for the player, and all the peculiarities of interpretation of this or that virtuoso. For steady use and to meet the general cultivated taste, standard normal music is best, and music so cut forms the best basis for those who wish by manual control to obtain a personal interpretation. On the other hand, keeping in view this desire for a specialised or individualised interpretation, the instrument is provided with extremely simple means by which anyone with special tastes may vary the expression to suit himself.

Still further control of expression is of course desirable. In many cases a much improved effect is produced by playing bass and treble at different degrees of force. This is accomplished in a simple manner by dividing the magnets into two groups, so that two different electromotive forces may be simultaneously used. The electromotive forces may be varied by means of the switches *W* and *Z* in Figs. 2 and 6. This improvement is incorporated in all the sixty-five-note standard players. If the author were to use the language of the piano-player advertising agent, he would describe this change as causing the accenting of individual notes and as bringing out the melody. This language is far too strong, and, like all exaggerated language, it is not only harmful in its direct untruth but it leaves one without terms to describe further improvements when actually made. Of course when the notes are thus divided into two groups all notes occurring simultaneously in either group are struck with equal force.

The musical advantage of a distinct individual accent is so great, however, that for two years the author has largely devoted his efforts to securing it, with the results that are shown in the eighty-eight-note player, Fig. 7. The simplest way to get an individual accent would be to practically duplicate the tape, using different electromotive forces on the parts. Imagine the music tape as made up of two parallel longitudinal bands, corresponding to a divided contact bar with a permanently maintained difference in potential. Imagine also the

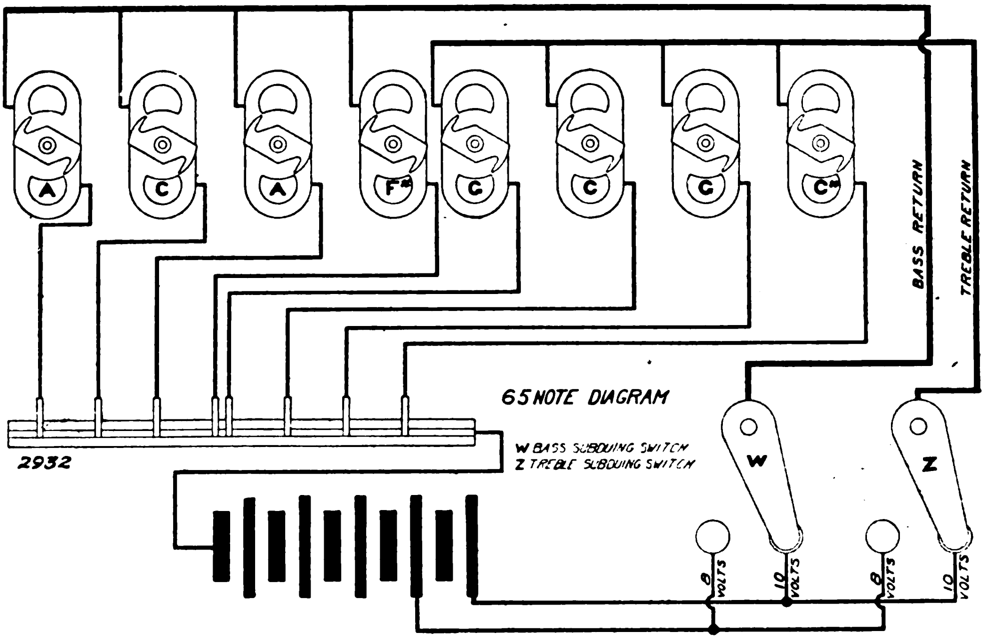


FIG. 6.
W, bass subduing switch; *Z*, treble subduing switch.

reading fingers, rheostats, and other accessories duplicated in each section, *i.e.*, one wire from each section for each magnet and piano key. Then it will be clear that a note would be accented or not according to which section carried the corresponding perforation. Unfortunately the system calls for music rolls nearly twice the width required for non-accenting rolls, greatly increases the cost of the rolls, and is otherwise clumsy.

To keep the roll within reasonable dimensions, and at the same time obtain the requisite control over the force of the blow supplied to different keys, was the subject of much thought. The author became satisfied that some system of grouping the notes must be used, and worked out several plans for the control of the groups. These plans, with the exception of that now being introduced into practice, it is unnecessary to describe. As to the grouping, the first idea that presented itself was, instead of simply dividing the scale into bass and treble, to cut it up into numerous sections. It would thus be possible to confine the accent within a narrow section. Unfortunately, until the section is reduced to the compass of but a single note it is always possible that it may contain a note which it would be undesirable to accent. Indeed, the narrower the section the more important it is that it should not contain a second accented note. The next idea that presented itself was to include in each group only notes of the same name: C's in one group, C sharps in another, and so on to the end of the scale. This is very much more satisfactory. Even if two notes should happen to be sounded in one group, as would occur sometimes, so that both might catch the accent, as the two are consonant, the effect would be substantially that of accenting the single note. Indeed, with the old-fashioned player the accenting of a note can often be simulated by cutting its octave to sound with it. The author thought it desirable, however, to go further than this, and on this octave grouping he superimposed the division into bass and treble. In consequence of this double grouping it is possible to obtain four different strengths of blow on the piano keys simultaneously. This capability, added to the power of control over expression already described, ought to satisfy the most exacting requirements.

The arrangements for carrying out this method are clearly shown in the diagram Fig. 7. The key-operating magnets are from one end of the circuit divided into two groups, and from the other end into twelve. The source of electromotive force has four terminals, ordinary 0, 2, 10, and 14 volts. Switches are so arranged that the wires leading to the magnets on the one side may be connected either to 0 or the 2-volt terminal, and on the other to either the 10 or the 14. These changes are independent of each other. It is therefore possible to supply any magnet with 8, 10, 12, or 14 volts at will. The switches are operated by quick-acting electro-magnets, and these, in turn, are controlled either by special perforations in the music-roll, or at will by the operator through specially provided buttons. At the will of the operator, also, any one or more of the means of expression may be left music-roll-controlled while he manually controls the rest. He may pick out that portion of the expression in which he feels he can best express his individuality, leaving the rest to the machine, or he may take into his hands the whole control and make the expression entirely his own.

A word as to the future. It would seem that the idea is still prevalent that a piano player must be necessarily inartistic. Logically, those who hold this idea should condemn the piano also, for piano playing is but mechanicalised harp playing. In all arts and crafts alike there is, and always will be, a place for hand work. Pioneer work falls to the hand, and in the arts especially there is a peculiar grace arising from the flexibility of the instrument. But power, accuracy, and precision are the features of the machine. The grace of the harp, and the fact that it allows of a more highly individualised playing, have in no wise prevented the more mechanical piano from becoming a hundred times more common, and the favourite instrument of great artists.

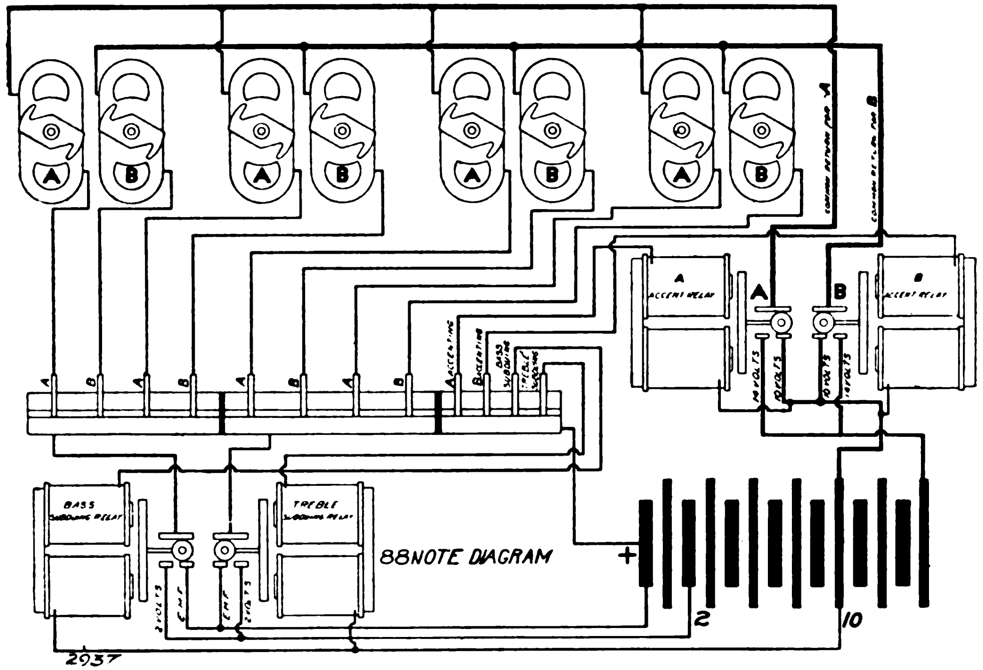


Fig. 7.

And while, as in passing from the harp to the piano, so in passing from the simple piano to the piano and player, there may be in some respects a loss, it would seem that for this loss there is a more than equivalent compensation; in speaking of compensation the author has in mind not only that thousands are reached by the player who otherwise would be deprived of all good music, but also that to some extent there are direct artistic compensations While the piano mechanism restricted the performer in some directions as compared with that of the harp, in others it opened out to him a wider field. And the player in turn will again widen the field. The composer will no longer have to think of the limitations of ten fingers on two hands. Consider what this may mean in transcriptions of orchestral music, or, if we have the daring, let us even dream of what it may mean in original piano music. There is another reason why our ultra-artistic piano lovers should take a more generous attitude towards the player. The growth of the piano trade, if it did not actually hinder the making of harps, at least did nothing to advance that art. The piano-playing business, on the other hand, tends to enormously increase the number of pianos in use, and each of these pianos should be recognised as the possible means of development of a future artist. And surely the struggling musician will be none the less likely to develop into an artist because he has at his disposal a machine which will make it possible for him to hear the great music of the world. As well might we say that it would be harmful to a young painter to be placed in possession of a set of photographs of the world's masterpieces in painting.

THE WORLD'S ELECTRIC PROGRESS.

Ships and Ship-building.

THE phase of electrical engineering which has to do with ships in the making and on the seas has assumed immense proportions. The great part now played by electricity in this essentially national industry is more the result of a steady, persistent encroachment than is the case with other industries wherein the advent of electrical means has been sudden and complete as an assault by storm. The first dynamos ever built were used in lighthouses off the British and French coasts; practice with the electric arc had become established in maritime circles before central stations on shore came into being. Yet, though applied electricity has been intimately connected with ships since the early eighties, nothing approaching finality has been reached; indeed, every month sees some noteworthy development in the electrical equipment of ships and dockyards. Whilst there has been a great deal of electrical work accomplished in this direction, there is an ever-widening field available for future development, and one which affords scope for every electrical manufacturer, whether he be engaged in making "accessories" or ten-thousand horse-power units.

The April number of The ELECTRICAL MAGAZINE will be chiefly devoted to a series of special articles dealing with the most modern phases of Electricity as Applied to Ships and Shipbuilding. In every case the articles will be written by engineers who have had actual practical experience of their respective subjects, and who are familiar with the latest developments and tendencies. We need not dwell upon the large industrial field which such a series of articles must necessarily cover: a passing glance at the variety of work and process appertaining to all shipyards, and from the modern battleship, full as a watch of engineering handiwork, to the merest coaster or tramp, will reveal the scope of our forthcoming special number. No effort on our part will be spared towards making the April number of this journal unique in so far as the nature and real commercial value of its contents are concerned. Electrical manufacturers who have specialities on their lists intended or suitable for dockyard and shipboard usage should send us particulars of the same as soon as possible. We shall be pleased also to hear from readers who are connected with, or interested in, any branch of the subject, and who may have suggestions or information to offer.

A Large Wood-working Plant.

THE capacity of the new mill of the Pennsylvania Lumber Company is about 175,000ft. per day. The greater part of the timber handled is hemlock and is prepared from the logs either as sawn planks or finished boards. The mill is of concrete and is fitted entirely for the electric drive, in most cases arrangements having been made to couple the motors direct to individual machines. The main generating plant is steam-driven, the boiler furnaces being arranged to consume the wood refuse of the mill. Three-phase alternating current was selected as being the right power system to adopt, and the circuit is arranged for 400 volts, 60 periods.

The logs are conveyed up an incline from the pond by means of a travelling chain or "jacker" which is driven by a 15b.h.p. motor fitted with self-contained back-gear, and running at 840r.p.m. The chain has a total length of 190ft. and is fitted with thirty-three steel dogs for gripping the logs. As the logs reach the top of the incline they are rolled either to the right or to the left. The mill equipment is provided in duplicate; that is, on each side of the chain discharge are band mills, gang edgers and trimmers arranged for receiving the logs.

The logs are first sawn into lumber by 8ft. band mills, each of which is operated by a 150h.p. motor running at 580r.p.m. From the band mills the sawn lumber is carried by live rolls and transfers to the one re-saw mill. Each set of seventeen 10in. by 24in. rolls is operated by a 7½b.h.p. back-geared motor running at 1120r.p.m.

The re-saw mill cuts the timber into thinner planks and boards, except in the case of the larger sizes, where the first cut by the band mills is sufficient. The re-saw is driven by a 150h.p. motor, 580r.p.m. On this re-saw mill are two 8ft. band wheels with 14in. face. The motor is connected by belt to the lower band-wheel shaft and gives to the saw a speed of about 9750ft. per minute.

From the re-saw the 1in. and 2in. material is carried by conveyors to the two-gang edgers, where the broader boards are sawn into standard sizes such as 2in. by 4in., 2in. by 6in., 2in. by 10in., 1in. by 4in., &c. Each of the edgers has eight 24in. saws and is direct-coupled to a 15b.h.p. motor operating at a speed of 1700r.p.m. From these machines the boards are carried on rolls to a row of swinging end-trimming saws. The trimmers consist of a row of saws mounted on swinging arms driven by belts from a line shaft, from which they are hung. One trimmer has eight saws and the other ten. Each set is operated by a 30b.h.p. motor running at 840r.p.m. The motor also drives a chain for conveying the finished standard length and section boards away. The ten-saw trimmer is known as the 6ft. to 22ft. automatic trimmer, and will handle material up to 6in. in thickness. The eight-saw trimmer is rated as a 6ft. to 24ft. automatic trimmer for use on material up to 11in. thick.

After being trimmed the boards are conveyed on the chain through the sorting shed, whence they are loaded into trucks by manual labour. The chain travels at the rate of 32ft. per minute, being driven by a 15b.h.p. back-geared motor running at 1120r.p.m.

Provision is also made for the removal of the refuse material by means of conveyors from the different mills. All sawdust is conveyed directly to the boiler room and automatically fired. From the band mills and the edgers the slabs are carried to slasher saws, which are saws mounted on a common shaft and spaced 4ft. apart. From the slashers the 4ft. lengths are taken, together with other refuse from the mills with the exception of the sawdust, by conveyors to a machine known as a "hog." A certain portion of this material, however, before reaching the hog, is taken out of the conveyor by hand and loaded for shipment to paper manufacturers. This pulp wood is used in the manufacture of paper and must have a length of 16in. and over. The balance of the refuse is cut into chips by the hog, from which it is dumped into trucks for shipment to neighbouring tanneries.

The slasher is operated by a 30b.h.p., 840r.p.m. motor, which also drives six conveyor chains, each 100ft. in length. The hog is driven by a 75b.h.p. motor, 690r.p.m., direct-connected. It has a large rotating element weighing approximately 2000lb., which carries twenty-four knives on a diameter of 60in. Owing to the weight of the moving element of the hog, the starting conditions are particularly severe, but the motor, which is of the slip-ring type, brings the machine up to speed quickly without undue overload. The main refuse conveyor for carrying refuse to the boiler room is driven by a 10b.h.p. motor running at a speed of 1120r.p.m.

* * *

Electrical Prospects in South America. As indicating the opportunities afforded by the western countries of South America for electrical trade, the report prepared by Mr. C. M. Pepper for the United

States Government will prove of no little value to electrical manufacturers of this country also. It would appear that there is every prospect of a considerable amount of electrical plant of all descriptions being required in the near future, and, whilst the American manufacturer has the advantage of being comparatively alongside the field, it is important to note that up to the present the result of German electrical trade enterprise predominates. That being so should at all events encourage British manufacturers to enter the lists with every assurance. In the words of Mr. Pepper, "the installation of electrical machinery may be characterised as one of the future industries" of the western part of South America. The Andes provide innumerable ideal large-power waterfalls; already there are hydro-electric plants in operation supplying the public lighting, traction, and small power users of several of the more important towns from Ecuador to Chile. The tramways of Quito and Guayaquil are now being converted for electrical operation; in the case of the latter it is proposed that the power shall be obtained from the Chimbo river, about fifty-five miles away.

There has been quite a considerable amount of electrical work done in Peru; the tramways power and public supply of Lima are supplied from a hydro-electric plant situated about thirty miles away. The country of Peru probably offers the most scope for immediate electrical power developments; most of the principal towns are provided with electricity supply, and every interest is taken in the subject of adopting electric power for private industrial concerns. There are schemes afoot, and being seriously considered, for the installation of heavy electrical generating plants to serve smelting works in the mountains. Then again the Peruvian Central Railway have under consideration the subject of electric operation. Another railway, at present only projected, but still very likely to be put down, is that of the Bolivian Government; this line will connect La Paz with the navigable waters of the Beni River, and, having gradients of one in six would almost certainly be electrified. It is in Bolivia that particular scope is offered for electric mining machinery; one district, Corocoro, is served by an extra high-tension system of sixty-five miles length. It is estimated that in this case the use of electricity in the mines means a saving of from 1½d. to 2d. per horse-power hour, according to the situation of the mine and the class of fuel available.

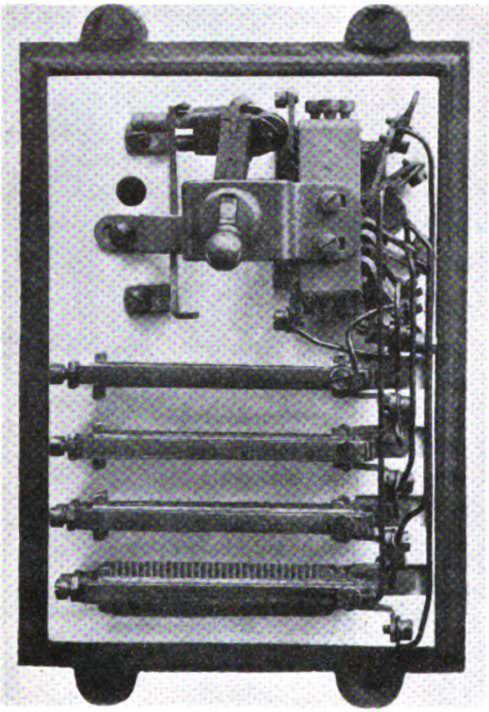
There are numerous enquiries for electrical plant circulating in Chile. The Germans are well established near Santiago, on the Maipo River, with a large hydro-electric scheme. The principal business to be done here is the electrical equipment of large industrial establishments; there are also several tramway and railway developments pending.

We can at this writing only give a brief outline of the electrical possibilities of those rapidly developing countries sharing a seaboard of upwards of 3000 miles, and existing on the immense natural resources of the western slopes and heights of the Andes Mountains. The important fact to the electrical engineer is that fuel is scarce and expensive—in some cases it is rendered doubly so by reason of the almost inaccessible sites where mineral wealth has compelled the establishment of power requiring plants. Water-power is available, and distance and altitude alike present no obstacle to electric transmission. There is work, plenty of it and profitable, waiting for the electric power engineer. Who will make the best effort to secure it?

⁂

Small Regulating Switch.

THE "Watkin" switch is one of those small electrical accessories which may be said to supply "a long felt want," in that it is a cheap and economical means of "turning the electric light down." It is really a novel form of variable resistance units invented by Messrs. Watkin & Payne, and which has been recently placed upon the market by Messrs. Adams & Co. Its



INTERIOR OF "WATKIN" SWITCH.

general sphere of usefulness is in connection with any kind of incandescent lamp, whether carbon or metal filament; but it is also meeting with much favour for regulating electric fans, heaters, cooking stoves, small motors, etc. One or more lamps with a maximum of 600 watts can be regulated so as to give seven degrees of illumination, reducing the current on each of the seven stops until on the lowest the actual saving of current on the circuit amounts to about 80 per cent., and, of course, at the same time the life of the lamp is considerably prolonged. In outward appearance the switch consists of an ornamental case only 4½in. by 6½in. with a tumbler switch; inside is fitted a series of resistances, made of a specially prepared composition resembling graphite, held in frames, and built up of short rods placed side by side and pressed together by screws. Each frame is differently "charged," *i.e.*, contains more or less of the resistance rods, and the frames or units are connected either in series, or in parallel, or both, according to what service is required of the switch. The handle of the switch is connected with a rocking lever, which carries at the inner end spring pistons, such as are used in lamp-holders, and a wheel travelling over contacts connected with the resistance frames.

Unlike the usual dimmer, the "Watkin" switch can be used on alternating or direct current. . It can be used either in series with the ordinary switch or in place of it, and is very neat and compact, while the internal construction is excellent. As already mentioned, the switch has seven steps of regulation, *i.e.*, when it is connected in series with a lamp, seven degrees of illumination may be obtained. On the last stop the illumination is reduced to a degree suitable for a night light. It is claimed that when this device is used, electric light becomes as easily regulated as gas. An apparatus of this kind must be particularly useful in hospitals, theatres, banks, etc. We understand that already it has been supplied to H.M. Government; also to the governments of New Zealand and India. In the latter case Messrs. Adams & Co. have been advised that it is to be specified for all future Government contracts for lighting and for regulating the speed of electric fans.

◆

Lift-controller.

A NEW form of Schureman lift controller which has been designed for use with alternating current where the control is by a rope passing through the lift, has been introduced by Wm. Geipel & Co. The controller is made for two-phase and three-phase motors only and is adapted for use where the lift is operated through a hand-rope passing through the cage. The controller is provided with a reversing switch at the top which is operated by the hand-rope. It has three definite positions, "up," "down," and "off" respectively. No intermediate positions are possible, so that accidental burning of the contacts is obviated. When the switch is closed, the motor starts with all resistance in circuit. This resistance, which is star-connected, is cut out by short-circuiting switches operated through a cam shaft which is actuated by a solenoid. This solenoid contains the only coil in the apparatus and it is heavily wound with a large margin of safety. The rate at which the resistance is cut out is regulated by the adjustment of a dash-pot.

The arrangement is such that upon the failure of the supply or opening of the reversing switch by the movement of the rope all resistance is instantly inserted, whilst it is not possible to reverse the direction of running without first inserting the resistance.

The switches are of heavy construction with carbon contacts, whilst every part of the apparatus is readily renewable. The resistance material consists of German silver wound in coils, in which a large margin of capacity is provided. The sizes range from 5h.p. to 25h.p.

◆

Lighting Dynamos for Motor-cars.

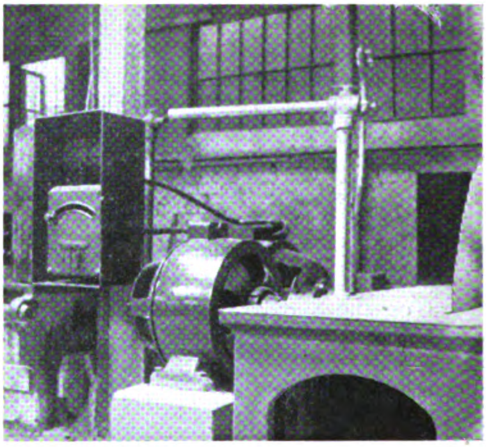
At the annual exhibition of automobiles in Paris, among the more important electrical novelties exhibited were two improved types of machine for lighting cars or other vehicles, and according to "L'Industrie Electrique" they have both met with approbation. It will be observed that for this service, although the dynamo is axle-driven, it must be arranged to maintain a uniform pressure independently of the car speed, and also that it should be a continuous-current machine on account of the batteries which are necessary to maintain the lighting current when the car is at rest.

In the system of Iglésis and Regner uniformity of pressure is obtained by automatically altering the position of the brushes relatively to the neutral axis. The special feature is that, instead of having a complicated movable brush carrier, the brushes are fixed, and the field casting as a whole is free to rotate to a limited extent about the axis of the machine. The amount of this field displacement depends on the mechanical reaction between the armature and the field. For starting up and for slow speeds there is provided a series winding in addition to the shunt winding; the series winding is cut out by a centrifugal switching arrangement, which comes into operation at the speed at which the shunt winding becomes effective. As stated, the two main brushes are fixed, but one end of the shunt is attached to a third brush which is adjustable, so that the voltage at a given speed may be altered within certain limits. An important feature of the device is that the battery may be used to drive the dynamo as a motor in order to start the engine of the car.

The second type is the "Phi" dynamo, by the Blériot Company. This machine has a normal output of 10amp. at 12 volts. It is bipolar, but has four separate field coils which are shunted across the brushes through four interrupters or field circuit breakers which are normally closed. When the speed of the machine exceeds 1200r.p.m. a cam, hinged at the end of the shaft, is forced out by centrifugal action and strikes, one after another, the four interrupter levers which are fixed about the centre line of the shaft. The levers are held up to their contacts by springs. In this way one out of the four field coils is cut out once every revolution, and the excitation is diminished as the speed increases. To prevent destructive sparking a small condenser is connected across each interrupter break; these four condensers are built into the dynamo body, in the spaces between the two field poles, and are thus well protected. A similar centrifugal arrangement connects and disconnects the battery at a predetermined speed. This consists of two contactors arranged in a similar manner to the weights in a centrifugal shaft-governor; when the critical speed is reached the contacts fly out and make connection between two rings, normally insulated from one another; these rings are connected to the battery and dynamo circuits respectively.

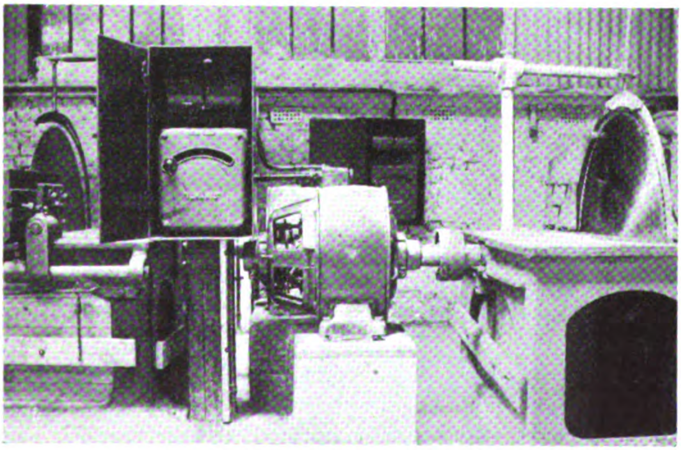
Small Industrial Plants.

In the various districts of London there are still many small factories and workshops which retain their steam or gas engine units. It is surprising that this should be the case, for the majority of the electricity supply companies now supply energy for power purposes at very low rates. With current available at the prices now charged, it can easily be shown that the most economical and efficient method of driving machinery in the smaller industries is by electric motor. There are many advantages to be gained in driving the workshop by electricity, the principal points being economy, efficiency, and cleanliness. A feature which should never be lost sight of by the small works proprietor in London and other large cities is the remarkably small space occupied by the electric motor as compared with any other type of power machine. Another factor of considerable weight in similar congested areas is that the electric motor is essentially a silent-running machine, neither does it pollute the atmosphere or, in fact, in any way cause discomfort or nuisance to the neighbourhood. When considering the respective merits of gas *versus* electric power, one must remember also that the electric motor is "ever ready": it can be stopped and started instantly as required, and the current economy secured by taking advantage of this property of the electrical plant is in itself a very considerable item in the small works' costs. One does not need to dilate on the merits or demerits of the gas engine in this respect; only too often it is "never ready"—what with valves to clean, ignition tubes to renew, oil-cups to fill, fly-wheels to pull round, &c., &c., all of which means that its owner only feels at all comfortable when the engine is finally under way, and not for worlds would he stop that engine during working hours, although it may be doing no actual work, for fear of the time, trouble, and general uncertainty of starting it away again.



"Witton" Motors in London Wood Shop.

In comparing the power figures of a small plant such as a wood-working factory driven by gas engine and one using electric motors, a great saving in the electrical shop can be shown. The power required to drive the complete shop machinery is 50h.p. If a gas engine be used, a long length of main shafting serves to distribute the power by several belts, and often also by intermediate shafts and further belting, to the several machines; it may be taken that if the



Typical Small-power Electric Plant in London Woodshop.

machines required 50h.p. for their operation, the gas engine would need to generate about 75h.p. The gas consumption of this engine would be about 18 cubic feet of gas per brake horse-power per hour, *i.e.*, a total consumption on load of 1350 cubic feet an hour. With gas at 2s. 6d. per 1000 cubic feet this gives a gas bill of £9 2s. per week of fifty-four working hours. The electric driving of such a workshop would almost certainly be effected by two or more motors. An ordinary machine equipment would include, say, two circular saws, three band-saws, six lathes, two planing machines, and a grindstone. These machines may be grouped and driven by three electric motors as follows:

Two 12½h.p. motors each driving a circular saw.

One 15h.p. motor driving the three band-saws and one planing machine.

One 10h.p. motor driving the six lathes, one planing machine, and the grindstone.

The current consumed driving the machinery as above is as follows:

Average current in units per hour = 20 units.

With current at one penny per unit, this gives a bill of £4 10s. per week of fifty-four working hours.

It will be seen that the electric plant gives a clear saving of £4 12s., or roughly 50 per cent., over gas-engine driving, as well as the many main advantages already pointed out.

The two illustrations shown are taken from actual photographs of motors installed by the General Electric Company, working in a similar shop to the one described above, and will give some idea of the compact and convenient arrangement of the machinery.

It is a fact that in this particular case the proprietor is saving £40 per year on his power bill by driving with electric motors in place of the gas engine previously used.

◆

The G.E.C. Dinner.

THE annual dinner of the General Electric Company, of which the nineteenth was held at the Trocadero on the 27th of last month, has come to be recognised as one of the most important gatherings of the British electrical industry. It is always immensely popular. Some 600 were present at the festive board, and the General Electric engineers entertained their friends from all parts of the kingdom in the manner most appreciated, and so well that the event will be generally considered as the best of the long series of its forerunners.

Mr. G. Byng, chairman of the General Electric Company, presided, and after the usual loyal toasts had been honoured, it fell to his lot to propose the toast of "Electrical Science and Industry." Many were the interesting pictures which Mr. Byng called to mind of the early days of electrical practice. This country led the field in those days both in manufacture and in science—we exported electrical goods in large quantities to all civilised parts of the world, including America, France, and Germany. More than that, we sent electrical text-books abroad, and, in short, we taught the world in matters electrical. Twenty years ago this country was supreme in electrical industry and invention: Mr. Byng recalled the world-famed names of the English inventors of those years, and asked a question, "Are we still leading?" We cannot do better than quote an extract from the speaker's answer to this question.

> "I am afraid that cannot be answered in the affirmative. Our British electrical industries are still vast and important and virile, but, alas! there are too many signs, to my mind, that we have lost our lead, and that to-day we have to follow in matters electrical. The records of our Patent Office show that we are not holding to-day that relative position which we held in the days of Swan and Hopkinson and Thomson. And what is the reason? . . . Let us diagnose correctly and learn the cause of our loss. There must be some difference in the conditions under which we electrical engineers work to-day as compared with those under which we worked twenty years ago. On many vital points there is no

difference. We still have our scientists, our inventors, our employers, and our workmen the same as we had them twenty years ago. We have the demand, we have the money, we have our factories and our machinery; our climate, our spirit, our enterprise and courage—all, I hope, are the same. I know of no war or other calamity or catastrophe which can account for it. Some say it is due to mistaken legislation, but, after all, this is to my mind a small matter. Some say it is due to education—technical education. I do not agree with those who contend that in matters of electrical education this country has anything to learn from other countries. British lads, rich or poor, have just the same chance as American or German boys to learn electrical science and to become proficient and efficient. If there is no difference in all these vital points, then where is the difference?

"I have come to the conclusion that the difference lies in the methods by which foreign Governments support their industries and those by which we here, in England, are supported by our Government.

"I see the foreign manufacturer of electrical machinery flourishing under a Protectionist tariff, whilst our industry began to languish ever since we felt the influence of free imports. That is my conviction."

In concluding his vigorous speech, Mr. Byng challenged anyone present to prove that our present state of trade is due to any other cause than the fiscal position under which we work, and offered a prize of twenty guineas to the writer of an essay which should prove him to be wrong in his opinions. He went further and said that he had reason to believe that in two or three years' time British electrical manufacture will be effected under conditions similar to those of our foreign competitors. When that good time comes then will order books be full and this country again occupy the foremost world position in electrical industry.

The following speaker was Mr. W. M. Mordey, who declined to believe that we were anything but successful as a nation in electrical matters. He quoted figures showing that our importations of electrical plant were comparatively small, and that the home use of electrical energy exceeded that of any Continental country per head of population.

Dr. Glazebrook spoke of the close connection which in this country always existed between electrical science and the industry, which connection was largely instrumental in making for the great progress which characterised British electrical engineering.

In proposing the toast of "Imperial Trade" Mr. Robert Hammond quoted figures as to the self-sustaining resources of the Empire. The Hon. C. H. Rason, Agent-General for Western Australia, responded, and directed attention to the fact that with a population of only four millions the trade of the Commonwealth aggregated about 125 millions a year. He spoke strongly in favour of "Protection." Mr. E. Grant Burls also responded to "Imperial Trade," and in doing so averred that he never let an order go abroad if he could possibly help it. As a sign of progress in India he mentioned the case of the Calcutta Mint, which is said to be the largest and most complete in the world. The machinery throughout is driven by electrical power, the installation having been put down in its entirety by the General Electric Company.

Prof. S. P. Thompson spoke in eulogistic terms of the General Electric Company and those who controlled its destinies, in reply to which Mr. H. Hirst, in returning thanks, referred in a few happy phrases to the work of his staff and the confidence with which the Company viewed the future.

◆

Commutator Sparking Voltage.

An interesting series of experiments were described by Mr. J. Liska, in the "Elektrotechnische Zeitschrift," concerning the critical voltages at which sparking would commence between commutators and brushes. From these tests it would appear that there is a minimum value of voltage at which a spark begins to be formed, this value depending upon the materials composing the commutator and brush. This minimum voltage is shown to be independent of the maximum voltage actually occurring, of the current, of the current density, of the mean temperature of the commutator, and of the speed of rotation, but it is in general different for different directions of the current. For instance, when the current passes from a carbon brush to a copper commutator, the minimum critical sparking e.m.f. is 14.5 volts. If the current passes in the other direction, the minimum critical sparking voltage is 22.5. For other materials of brushes, the minimum voltages were found to be as given in the following table:—

BRUSH.	Anode Volts.	Cathode Volts.
Le Carbone "Z"	14.5	22.5
Morganite "I"	14.5	16
Copper-carbon, Endruweit system ..	14.5	21
Copper, Endruweit system	14	14
Copper-brass, Ringsdorff	15	12.5

No sparking can occur at a commutator if the actual voltage does not exceed the minimum critical voltage. There is no great difference between the minimum critical voltages for metallic and carbon brushes, but this does not contradict the fact that metallic brushes are more liable to heavy sparking. The explanation offered is that when the voltage gets higher than the minimum critical voltage, the strength of the spark which occurs is determined by the energy, and with metallic brushes the current is stronger on account of the smaller transition resistance.

◆

Mechanical Test for High-Tension Glass Insulators.

A PAPER read by Prof. A. S. Richey and Dr. Frederick Bonnet before the Worcester Polytechnic Institute, U.S.A., described a method of testing high-tension glass insulators which served to show defects in annealing that could not be detected by other methods. Experience had shown that of two types of insulators, made by two different manufacturers so as to be practically identical in form and using glass of the same chemical composition, one gave excellent results in service, while the other was subject to excessive breakage. Tests by means of polarised light proved that the latter type was subjected to stresses caused by improper annealing, while in the former there was an almost entire absence of stresses.

In carrying out the tests each insulator was so mounted that when it was rotated about its pin axis the same thickness of glass skirt was always presented between the polariser and the analyser, which previously had been arranged so as to allow no light to pass. Stresses in the insulator were indicated by the varying intensity of light and by colour changes. The insulators showing stresses had been poorly annealed. Under service conditions they became heated on account of conductive leakage and were destroyed.

◆

Apparatus for Testing Variation in Angular Velocity.

THE necessity of prime movers having as nearly a constant angular velocity as possible, where the driving of alternators in parallel is the duty, is well known. With the standard makes of high-speed steam engines this point has been well taken care of, and it is rather the exception than the rule to find the percentage variation allowable definitely specified when high-speed steam sets are required. The use of large gas engines has however brought this factor of even rate of rotation into prominence, and it may be taken that not only are definite guarantees required of gas-engine builders, but that tests must be made to confirm these figures. These variations can only be ascertained by actual test, and the following description of an apparatus suitable for the purpose will doubtless prove of value to many electrical men who have the handling of alternate-current power generator

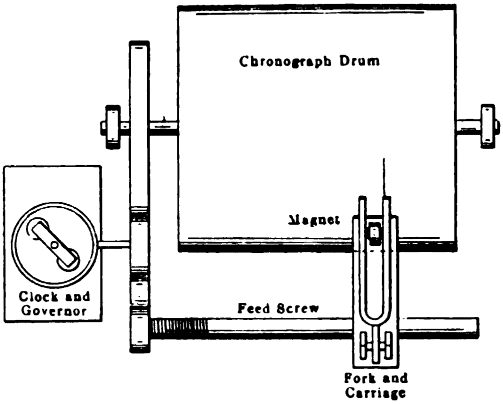


FIG. 1.

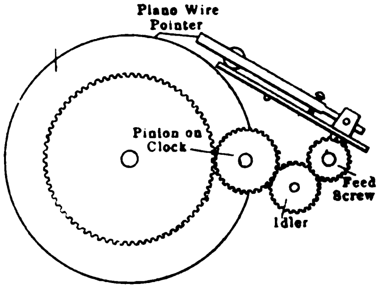


FIG. 2.

business. The instrument, which was described by a correspondent of "Power," who stated that it had given excellent results, consists of a hollow drum made of an alloy of 75 per cent. aluminium and 25 per cent. zinc fastened to a spider and suitably mounted on a bedplate of the same material. The drum is connected to a clock and governor by gears, as is also the feed screw, on which is mounted a tuning fork vibrating 100 times per second. The ratio of the gears and the feed screw is such that the carriage moves about half an inch for each revolution of the drum. Near the end of the tuning fork is mounted a small magnet which keeps the fork in vibration. A general idea of the arrangement may be obtained from Figs. 1 and 2.

When any engine is to be tested six or eight small holes are drilled and tapped at equal distances on the edge of the rim of the flywheel; into these holes are screwed steel pins about 3in. long. The chronograph is connected as shown in Fig. 3. A piece of blueprint paper is placed on the drum and the pointer at the end of the fork draws a continuous record, Fig. 4. A brass nozzle is so placed that a jet of salt water issuing from it will strike each pin in turn, closing the condenser

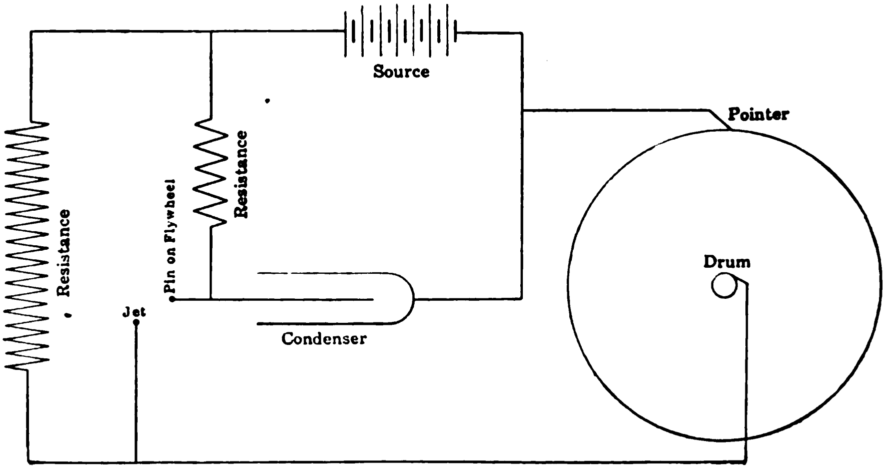


FIG. 3.

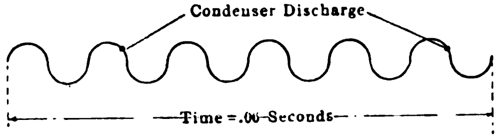


FIG. 4.

circuit, as shown in Fig. 3, and in discharging through the drum make a spot on the record. After the record has been taken it is a very easy matter to determine the variation in the velocity of the flywheel by comparing the space in time between the spots on the record.

⁂

The Advantages of Cooling the Gas-Engine Charge.

A VALUABLE series of experiments have been made by Prof. Junkers of the Technische Hochschule, Aachen, as to the effect of cooling the charge mixture of large gas engines. The investigations proved that the capacity and the efficiency of the engines were improved very appreciably. The engine used for the work was one of the Oechelhauser two-stroke type. With the engine running under normal conditions and without cooling the charge, at its maximum capacity, the mean pressure in the working cylinder was 4.55 atmospheres, and the power developed 395i.h.p. The charge temperature was 90.5deg. C. By cooling the charge by 60deg. C., *i.e.*, from 90.5deg. C. to 30.5deg. C., the mean cylinder pressure became 5.29 atmospheres and the indicated h.p. rose to 460. This shows a theoretical increase of capacity, with cooling, of 0.198 of the amount attained without cooling. The practical increase was 0.165 of the ordinary result. In other words, by cooling the charge the capacity of the engine was increased by 17 per cent. beyond what was attainable without cooling.

The charging pump of the engine absorbed 55i.h.p. in the first and 51i.h.p. in the second instance. But this difference is probably due to the fact that the charging pump was too large for ordinary operation and its intake had to be throttled, while, owing to the larger free volume taken when cooling the charge, the throttle was opened and its resistance diminished. The cooler carried away approximately 38,500 heat units per hour from the charge. A comparison of heat absorption by cooling water with and without mixture cooling, respectively, gives the following results, it being assumed that 700 heat units per h.p.-hour were being carried away by the cooling water: Output without intercooling = 395i.h.p ; loss to cooling water of cylinder = 700 × 395 = 276,500 heat units per hour. Output with intercooling = 460i.h.p., and it was ascertained that the heat loss to the cooling water for the cylinder was not larger than before, 276,500 heat units per hour. In addition, there were wasted 38,500 heat units for cooling, making a total of 315,000 heat units per hour. An engine not equipped with the cooling device would lose, for the same output of 460h.p., 460 × 700 = 322,000 heat units per hour. It follows that the cooling of the charge has also a favourable effect on the total heat carried away per unit of power developed.

As a further advantage of the cold charge system it may be mentioned that the number of misfires is reduced, whereby the average mechanical efficiency of the engine is increased. Also, part of the water vapour of the charge is separated out by the cooler, by condensation, which must have a favourable effect on the internal combustion.

It is pointed out that even these effects do not represent the total advantage which would be gained by an extension of the principle to the cooling of the charge in compression, or rather by permitting of higher degrees of compression. By thus increasing the compression pressures, a far greater increase in capacity could be obtained; thus a cooling of the charge by 30deg. C. will allow of an increase in compression of from 13 to 21 atmospheres, without increasing the cylinder temperatures above normal. Tests with a Körting engine working with producer gas and driving an electric generator under these conditions, showed an increase of 12 per cent. in the electrical output. It was also noticed that pre-ignition or back-firing, which had been a fault of this particular set, disappeared entirely whilst the engine was running with the cooled charge.

* * *

Large Héroult Electric Steel Furnaces.

THE United States Steel Corporation has, after a thorough investigation, decided to install Héroult electric furnaces at two of its plants. A 15-ton Héroult furnace is now being constructed for the South Chicago works of the Illinois Steel Company, and one of the same size for the Worcester plant of the American Steel and Wire Company. A third installation will probably be made later at the Homestead plant. The capacity of each of these furnaces is about 300 tons per twenty-four hours. At the Chicago plant the process will be applied to the manufacture of a special steel rail of high-grade quality, and at the Worcester plant the product will be used for a special grade of wire. In the former the electric furnace will take molten steel from Bessemer converters and in the latter from open-hearth furnaces. The electric process is therefore simply a refining process in which the phosphorus and sulphur are reduced to amounts otherwise attainable only in crucible steel practice. At the same time the steel is thoroughly deoxidized and freed from all particles of slag. The largest Héroult steel furnaces formally installed have a capacity of five tons. While the 15-ton furnaces of the U.S. Steel Corporation thus represent a trebling of capacity, the company contemplates the installation of even larger furnaces in future.

* * *

Electric Smelting Furnaces.

To those who are interested in the progress of the many experiments now being made towards the perfecting of electric iron smelting furnaces, the report of Dr. Eugene Haanel, Director of Mines for Canada, concerning his recent inspection of the smelting furnace in Dumnarfvet, Sweden, will carry much weight. In his preliminary report on the experiments at Sault Ste. Marie, in 1905, Dr. Haanel stated that the furnace there tried needed certain modifications to render it a commercial possibility. This report awakened lively interest in Sweden, where the conditions are similar to those of central Canada. A company was organised, able young engineers were put in charge, work was carried on for a year and a half at a cost of some £22,000, and the furnaces were built, each showing correction of faults observed in preceding ones. Upon attaining what it considered a commercial furnace, the company invited Dr. Haanel to inspect and pronounce upon it. As a result, he is confident that the new method is a commercial success. The furnace is very similar to a blast furnace, in which the tuyeres, for introducing the blast, are replaced by electrodes. A three-phase current is employed, and about 700h.p. is delivered to the furnace. Dr. Haanel assured himself that the furnace in every way met his expectations as a solution of the problem of constructing an electric furnace on a commercial scale. The furnace worked very quietly, and the charge passed down the shaft gradually and uniformly, the electrodes requiring no regulation, not having been moved for five days. Should the new furnace prove to be all that is expected of it, there is at once a new and profitable industry opened up for Canada in particular. In the Dominion there are enormous fields of iron ore, the utilisation of which has been impeded by the unfortunate natural scarcity of furnace fuel. "White coal," that is, water power, is present in abundance and the method which permits of the use of power from hydro-electric plants as the direct smelting agent will have far-reaching effects and undoubtedly establish a vast Canadian iron industry.

In addition to this work at the Dumnarfvet works, there has been invented a steel furnace which also promises great results.

In this furnace a three-phase current and two electrodes are used, the bottom of the furnace furnishing the third electrode. The special advantage of this construction is that the three-phase current produces a rotation of the bath in a vertical plane, thus bringing new material continually into the slag line for purification.

* * *

Battery Rooms. The following suggestions as to the general arrangement and fitting of battery rooms were included in an interesting article in a recent number of "L'Electricien": Batteries should be installed in a room in the vicinity of the engine room, but the battery room should serve for no other purpose; it should be easily accessible, well lighted, dry, easy to air, and not exposed to great variations of temperature. Dust, vapours, dangerous gases and violent jars in the room should be prevented. There should be no iron pipes or columns in the room, if these can possibly be avoided, and if they are necessary, then they should be well covered with an enamel lacquer which is not attacked by acids. For lighting the room, only incandescent lamps should be used. In order to maintain the batteries in good working order, only those rooms in which the temperature is liable to fall extremely low should be heated, but never by an open fire. Stationary batteries, on account of their heavy weight, should be placed on solid beams. In cellars the ground should be well stamped, and covered with a layer of brick or cement. If the ground is sandy a layer of concrete about three inches thick should be put under the brick, and a mixture of hot coal tar and asphalt should be poured into the spaces between the bricks after they have been filled up with fine sand to about half-an-inch from the surface.

If the battery is to be installed above the cellar, a solid floor should be built in keeping with the weight of the battery and capable of preventing any spilt acid from penetrating into the rooms below. The floor should be perfectly level and well protected against the destructive action of the acid. The walls, ceiling, electric conductors and iron parts should be covered with an enamel lacquer that is not attacked by acid and does not contain alcohol. Cement-covered walls must be perfectly dry before being painted, as otherwise the paint will peel off. If the accumulator room is directly under the roof of a building, a false ceiling should be erected to prevent any water condensing under the roof from falling into the batteries. Rooms should always be painted with acid-resisting enamel or lacquer before the installation of the batteries, or at any rate before filling and charging the cells, as these operations make the walls damp. Facilities should be provided for full and ample ventilation, which is especially necessary when the charging of the batteries approaches completion.

* * *

Electric Motors for Brick Works. In a paper read by Mr. E. A. Lof before the Iowa Brick and Tile Association, the advantages of electric power for operating brick and tile plants were presented, and the following figures given as to the power requirements of the various machines in a brick plant with a yearly capacity of 25,000,000 bricks:

Brick machine	75h.p.
Pug mill	50h.p.
Dry pans, each	35h.p.
Represses and cutters	35h.p.
Elevators	20h.p.
Conveyors	8h.p.
Exhaust fan	50h.p.
Disc fan	10h.p.

The aggregate for such a plant is thus about 250h.p. The fans would run twenty-four hours, the rest of the machines about ten hours per day. The average load on the motors throughout the day would be about 80 per cent. Another service in brick making which could well be adapted for the electric motor is the driving of haulage for conveying the clay from the pit to the machines. The author quotes an instance where the use of an electric plant of this character introduced a labour saving of ten men. Central station engineers having brickyards in their districts would find this class of prospective business worth looking into.

* * *

A Tax for Electricity.

A GERMAN correspondent sends us some interesting details of the novel efforts which are being made by the Government of that country to increase its revenue. The German Empire is noted for the large number of taxes, and nearly every year new ones are introduced. While some are just, inasmuch as they tax luxuries, some of those which are proposed this year do not show that the people who will be required to pay are to be treated with justice. A consideration of the proposed tax for electricity will show how much, if it becomes law, it will affect the German electrical industry and perhaps the foreign market imports as well as exports.

The rules concerning the tax for gas and electric current as a source of light, heat, and power, contain no less than thirty-one paragraphs. Only those products to be used in the home country are to be taxed. Five per cent. of the selling price must be paid for electric power, but not exceeding ½pfg. per kw.-hour; only the plant which cannot produce more than 1½kw. is to be free from this tax. In addition, 10pfg. must be paid for each bulb lamp up to 10 watts capacity; 20pfg. for 50-watt lamps; 30pfg. for 100-watt lamps; and 50pfg. for lamps exceeding 100 watts. One mark is the duty for each kilogram of arc lamp carbons; and similar taxes are proposed for mercury and other lamps up to 100 watts. The amount of the tax must be indicated on the package by affixing a label, and this has to be done in the factory before the products are sent out. These packages from inland as well as abroad must be securely sealed and the contents must be stated, including the number of pieces, quality, capacity, &c., so that the authorities can easily see the value. Any fraud in this respect will be heavily punished, the highest penalty being two years imprisonment.

It is clear that neither the manufacturers nor consumers will welcome such a tax, and from the interesting discussions in the daily Press it is being bitterly fought. It is true that electricity is not yet at its height, and many inventions and improvements are still to be expected. A tax of this description would undoubtedly prevent progress, and, our correspondent remarks, the foreign electrical industry will have no difficulty in overtaking Germany, which has now secured so many advantages. We know that scientific research is pursued in that country perhaps more than anywhere else, and electricity is one of the chief media used in such researches. But it is not in laboratories where the shoe will really pinch, it is in the small workshop and factory where electric power and light are extensively being used. Especially in agricultural districts there is a great future for the electric motor to replace the heavy and cumbersome steam tractor now frequently used for ploughing, grass cutting, pumping, harvesting, thrashing, and driving various kinds of machinery on the farm. For such farms having an area over thirteen acres it will pay to provide a private electric plant.

A similar retarding influence will take place in the electro-chemical industry, wherein Germany holds a leading position; for instance, in manufacturing aluminium, calcium carbide, nitrogen of lime, and many other products. The application of electric power for railways is seriously considered in the German Empire, and it was intended to electrify the Berlin metropolitan railway in the next two years to increase its capacity and speed. All such projects will be much delayed or not carried out at all if the tax is introduced. Enormous powers are available in Germany's waterfalls, especially in Bavaria and the South, where one and one half million horse-power could be utilized and turned into electricity, especially as these districts have very few coalfields. More than four-fifths of this water-power is not yet exploited, and if the tax becomes law this state of affairs is likely to continue for an indefinite period. In short it would seem that such a tax will considerably hinder progress in various industries, and hamper the large manufacturer as well as the small one, the producer and the consumer.

* * *

Public Electric Supply in Germany.

OUR correspondent supplements his remarks anent electric taxation with some particulars of the present condition of the electrical field in Germany.

There are 1055 electric plants in communities of over 5000 inhabitants. These represent naturally a very considerable capital; Cologne has spent 12.4 million marks; Hanover, 7.8; Frankfort, 15.8; and Charlottenburg, 10 millions. These electric supply systems sold in the past year from 11 to 24 million kilowatt hours respectively. Current was supplied for 106,000 glow-lamps in Breslau, for 218,000 in Charlottenburg, 112,000 in Dusseldorf, 367,000 in Frankfort The total power of the electric motors connected in those cities to the public supply was 8126h.p., 7492h.p., 5605h.p., and 7590h.p. respectively.

There is no city in Germany of over 50,000 inhabitants not owning an electric plant, and 75 per cent. of these are municipal property. In many smaller places the community purchases current from private industrial plants, factories, &c., for city lighting and public buildings. The percentage of municipal plants is rising every year, but still a large number of plants are in private hands; besides the famous Berlin Electricitäts Werke there are seven large concerns owning public electric central stations. The city of Berlin receives 10 per cent. of the company's receipts from furnishing light and power, besides half of the net profit, which exceeds 5 per cent. Berlin took last year over three million marks in current from private plants; Hamburg one million. Other cities own plants but lease them to private concerns. The production costs of the electric station are higher than for gas, and, as the electric stations have to base their prices upon those of the gas supply, many of them are not profitable; in many cities there are deficits, if the depreciation, interest, repairs, &c., items are taken into account.

The price of current is very variable and depends generally on the total consumption. According to a private estimate of 160 municipal and private plants, the price per kw.-hour with 12 per cent. of the works was over 60pfg., with 32 per cent. below 60pfg.; for motor current, with 20 per cent. of the works, over 20pfg. In the case of twenty-two plants the charges for motor current averaged less than 18pfg. There were eleven stations where the direct cost of production was 24pfg., so they operated with a considerable deficit. The opinion prevails, therefore, that with such low prices the costs of generating the current are not covered, while on the other hand it must be admitted that the current is furnished in the day-time, when the plants are more or less idle. Besides cheap prices the great decentralisation of the electric supply is largely responsible for these unsatisfactory results.

* * *

Electrical Trades Benevolent Institution.

SIR WM. H. PREECE, K.C.B., F.R.S., is to preside at the forthcoming festival dinner, which will be held at the Whitehall Rooms, Hotel Metropole, on March 30th, in aid of the above. This is the first function of its kind held in connection with this Institution, and a great deal of work has been done by the Special Committee appointed for its organization; there are indications that the effort has awakened widespread interest, and it is anticipated that a considerable sum of money will be forthcoming as a result for presentation to the funds.

As the benefits of the Institution are available for an exceedingly large class, it is desirable that the funds should be increased so far as possible, and we are very pleased to take this opportunity of directing the reader's attention to a matter which is of interest to all who are directly connected with the electrical industry, or who indirectly benefit from progress in electrical work, either as suppliers of raw materials for the construction of electrical goods, or as users of electric light and power, telegraph, telephone or signalling apparatus. The offices of the Institution are at Ridler Place, Holland Street, Blackfriars, S.E., and Mr. Walter Davenport is the Secretary.

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Practical Coal-Mining.

WITH the sixth volume, just issued, the very complete work entitled "Practical Coal-Mining" is completed. We have from time to time given reviews of the various sections of this book as they appeared. In this last volume the subjects dealt with include mine surveying, with the instruments used for this work and the methods of applying them for surface and underground surveying. Another section treated in this volume is that which deals with the preparation of coal for the market: in three chapters the subject is divided into the circulation of mine wagons at the surface, the weighing of coal, and generally the method of dealing quickly with the product on the surface. This is followed by descriptions of screening and picking plants and coal-washing machines. A valuable section of the book is that which treats of the coking of coal and the recovery of bye-products, a phase of colliery work in which electrical men are perforce interested to-day because of the frequency with which it is brought into evidence when any large colliery electric plant is projected.

The concluding chapters will be found of exceptional interest in that they deal with the economies of coal getting and marketing. In this stage of the book, wages and labour questions are entered into; conciliation boards, trade combines, negotiation of contracts and general market organisation are all given due and full attention.

The series is published by the Gresham Publishing Company, of 34, Southampton Street, Strand, London, and is written by many of the leading lights of the mining and engineering professions under the editorship of W. S. Boulton. For the benefit of those students to whom the item of text-books is a main consideration it is as well to point out that the volumes can be obtained on the instalment system.

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Correction.

READERS should note that the illustrations Figs. 3 and 4 which appeared with the article entitled "Progress in Photo-Telegraphy" in last month's ELECTRICAL MAGAZINE, were inadvertently transposed.

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NOTE.

Manufacturers are invited to send us particulars of any new machine or apparatus which they may be introducing, or notes of any important contracts recently carried out. We are always pleased to publish notices of this character which are of real interest and value to our readers. Where possible, illustrations should accompany such matter.

Particular attention *is directed to the next issue of The ELECTRICAL MAGAZINE, which will be a Special Double Number dealing with the Applications of Electricity in Ships and Shipbuilding.*

Manufacturers who are interested in this class of work should send us particulars of their work in connection with same at the earliest possible moment.

The

Electrical Magazine.

VOL. XI. NO. 4. APRIL 15th, 1909.

THE ELECTRIC PROPULSION OF SHIPS.

FEW subjects which are engaging the attention of the engineering world to-day are comparable, either in scientific interest or in practical importance —*i.e.*, commercially—with the generation and transmission of power for main marine propulsion and speed regulation. It is believed that a reference to this all-important development of electric-marine engineering will be of more than passing interest to a wide circle of readers, many of whom have not hitherto paid attention to the rapid advances recently made in the application of the electric motor to the purpose of navigation. The industry of equipping and operating electrically-driven ships is still new, and only few boats have so far been fitted with electrical power for main propulsion, but in recent years a great deal of instructive experimental work has been done, and in many instances marked practical success has been attained.

No attempt will be made here to give details of every electrically-driven craft built up to date, but a certain number of possibly interesting applications of the electric motor will be pointed out, illustrative of the art, and of its possible evolution in larger units than have up to the present been attempted. The success of electrical locomotion on land is now well established and millions of electrical horse-power are to day being utilised in many and varying industries, and in such large plant units that they approximate in size to those which are to be found applied to the purpose of ship propulsion with direct-coupled steam engines and steam turbines with more or less commercial success.

Whilst, however, these applications have made progress in many ways, marine electrical propulsion has been receiving serious attention, and for some few years has been more or less quietly asserting itself as an art and an industry. The time has consequently arrived when the subject of electrically-propelled ships may be discussed with pleasure and interest, especially as the steam turbine in various forms, and the suction gas engine and petroleum engine of enormous powers have been developed to the point of proved commercial success as high-speed light-weight prime-movers.

The propulsion of ships was one of those greater power applications of electricity which were necessarily delayed pending the perfection of means of generating large quantities of electrical power cheaply, and the great advance in the design, construction, and operation of the above prime-movers has made the cheap production of current possible in machines of very large output capacity, and making the successful application of electricity into this large, untapped, and important field, appear within sight; matters have so far progressed towards the use of electricity as the main power agent on shipboard, that it is safe to say the near

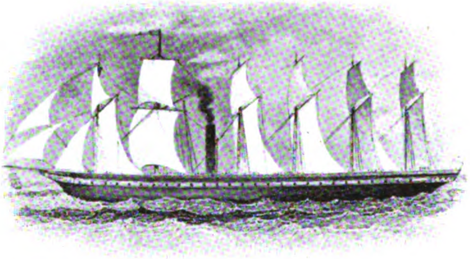

FIG. 1. THE FIRST LARGE STEAM VESSEL WITH SCREW PROPELLER (1844).

future will almost certainly see some very big advances in marine electrical engineering, to the benefit of the British electrical and shipping trades generally, both of which are ever more and more severely suffering from advanced foreign competition. The author believes that the following particulars will possibly indicate in at least one direction how, with a little modern encouragement, the vast potentialities of electricity may be secured for the benefit of British capital and labour, besides cheapening the cost of general transportation by sea of passengers and freight; and, by reviewing the whole position as it now stands with its practical prospects, indicate that there is good reason for confidence in the immediate future.

For the first time in the history of electrical engineering—nearly seventy-one years ago, 1838—Prof. Jacobi, a distinguished physicist and electrician, residing in St. Petersburg, made a demonstration on the Neva of what could be accomplished with the electric motor as a means of propulsion for boats, and towards the expenses of the experiment the Emperor Nicholas contributed about £2500. Prof. Jacobi employed a type of motor which had already attracted considerable attention, having been before the Académie des Sciences of Paris in 1834. The attempt was the first on record and is a proof of the originality and versatality in electrical investigation that made Prof. Jacobi one of the discoverers of the great modern art of electrical engineering.

Just what led the Emperor of Russia to take an interest in the application of electricity to marine propulsion and spend this money on it is not known, but it is generally supposed that these tests, like others undertaken in Europe about that time, were due very largely to the exhibitions made in London by Thomas Davenport, the Vermont blacksmith, of his electric motors, &c. The Jacobi boat on the Neva derived its current from primary batteries, and the motor propelled it at a speed which never exceeded about three miles per hour; the motor was geared to paddle wheels, the boat being 28ft. long, 7ft. wide, and 2ft. 8in. in draught, and she carried as many as fourteen passengers. They were able to navigate for several hours on the river Neva, but the power developed, through proceeding from a battery of no less than 128 large Grove cells, never exceeded $\frac{3}{4}$b.h.p., and such a small effect from such a large source of energy completely discouraged the inventor, who always afterwards considered this application of electricity as impracticable for industrial purposes.

Since that time and the later work in England of Robert Hunt and of G. E. Dering in 1856, and of Count de Moulins in France in 1866, there have been many other attempts to apply batteries to the propulsion of ships, but the experiments have nowhere resulted in lasting "commercial" success. The prospects of seeing a large ship laboriously hauling an acre or two of batteries through the surf was almost too much to expect, and although many other interesting attempts were made from time to time, it remained

FIG. 2. THE "LUSITANIA."

FIG. 3. H.M.S. "DREADNOUGHT," FITTED WITH TEN STEAM TURBINES ON FAN PROPELLERS.

for the introduction of high-speed and efficient prime-movers, such as steam turbines and internal combustion engines, together with the very great advance in the art of dynamo electric machinery construction, before the application of the electric motor could be reasonably put forward as a means of propeller shaft driving for main marine work.

The next notable step in this interesting sequence of pioneer work took place in 1903, also at St. Petersburg, when a vessel was constructed and put into service by "Société Nobel Frères." In this the craft was a tank vessel of 1150 tons displacement, intended to carry oil on the Volga and in the Caspian Sea. The propulsive plant of this vessel consisted of three Diesel engines driving continuous-current dynamos which supplied current to three electric motors; each of the motors served to drive one of the three propellers fitted, the whole control being carried out from the bridge. The regulation was effected by means of varying the exciting current of both the generators and the motors, by which means also the reversing of the propellers was effected. The vessel speed was, however, only very low: light, 8 knots; loaded, 7.4 knots; the total power of the engines was 360b.h.p. The generating plant was situated about amid-ships, while the motors were placed right aft in a separate motor room. The control being arranged from the bridge, the engine-room staff did not know in what direction the propellers were running, whilst, on the other hand, the staff of the motor room, knowing it, were unable to bring about any change. The complete control of the drive was carried out solely by the captain on the bridge, and he steered and manœuvred the ship without having any contact with the engine-room staff. The consequence of this was that no such thing as mistakes in receiving orders could possibly take place, such has have been known to occur on ships where the ordinary signals have to be given to the engine room before any alteration in speed or direction of the propellers can be made. The importance of this fact is self-evident, and it will perhaps not be forgotten how the large German liner at Dover some time ago was driven by mistaken orders on to the strong granite pier and sustained severe damage in consequence.

As above stated, the advent of the steam turbine has brought about conditions that make the "commercially successful" application of the electric motor and apparatus possible in very large units, and some very interesting suggestions have of recent years been devised. Amongst those which deserve mention may be mentioned the system brought out by an American electrical engineer, in which it is proposed to use a high-speed steam turbine. The principle of this arrangement is shown in Fig. 6.

It will be observed that the steam turbine drives a single-phase alternating-current armature which runs in a separately excited

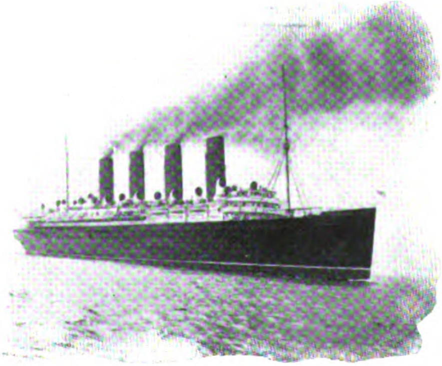

FIG. 4. THE "MAURETANIA."

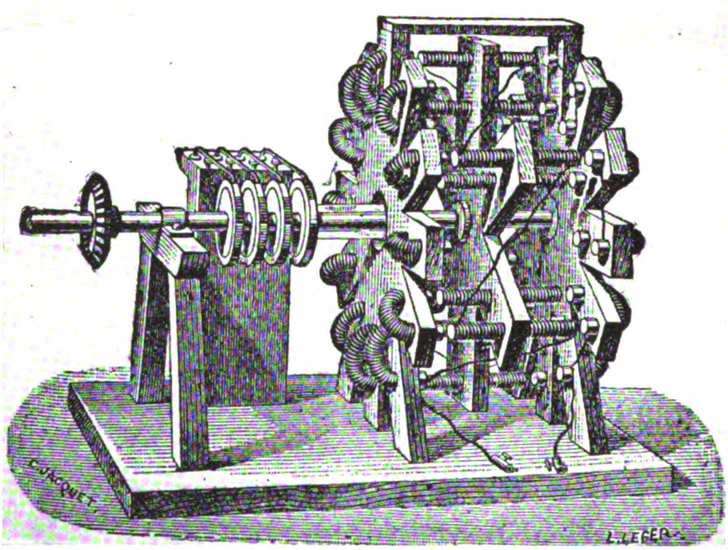

FIG. 5. THE FIRST MOTOR USED FOR MARINE PROPULSION (1838).

field, which field is mounted on the propeller shaft and revolves with the propeller. The current that is generated in the armature is taken to a transformer primary and, by means of tappings, the single-phase series-wound motor, the armature of which is also mounted on the propeller shaft, is allowed to assist in turning the propeller, assisting the torque that is produced at the air-gap of the alternator. Reversing is carried out by means of the two-way switch shown. As to the merits of this system, it is questionable whether the weight of the single-phase plant, and the fact that the gear ratio is only two to one as regards speed reduction, are not prohibitive; and it is also to be noted that in all probability the system does not provide the best application that could be put forward in the interests of electrical engineering for this purpose. A further disadvantage is that in this case the turbine must be in line with the propeller shaft, and should any turbine be under repair, the corresponding propeller is perforce also out of work. Another point is that in large powers the weight of the revolving field of the alternator is considerable.

A somewhat similar application is to be found in Fig. 7; this is also the suggestion of an American engineer, but in this case it is

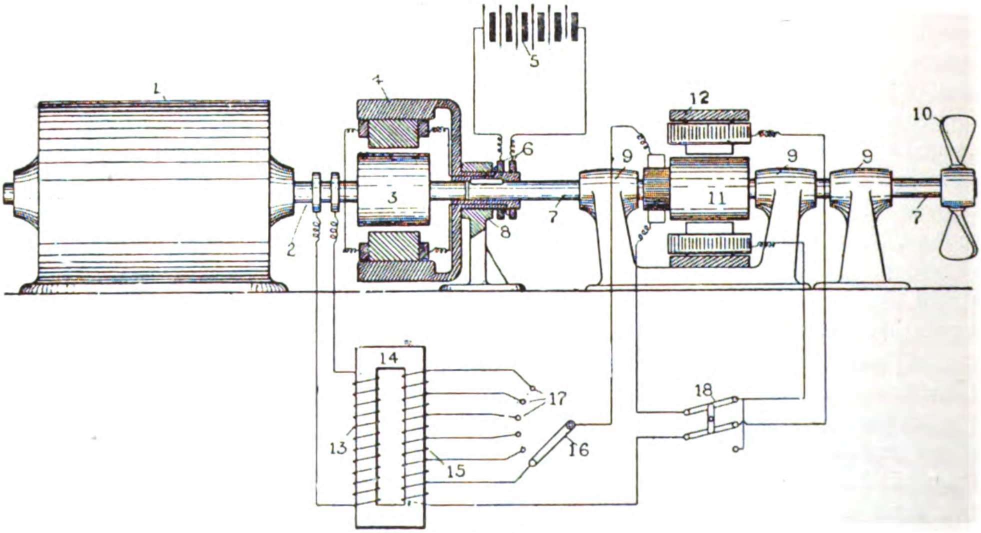

FIG. 6.

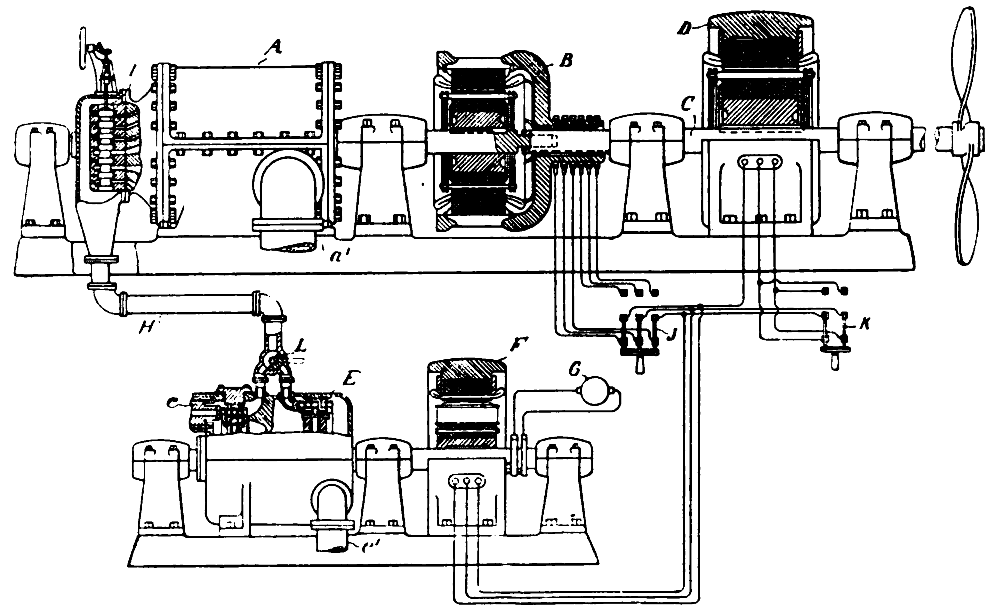

Fig. 7.

proposed to use polyphase alternating-current apparatus. It will be noticed that the steam turbine drives a short-circuited rotor in a revolving three-phase armature, the armature being excited by three-phase current from the smaller turbine alternator shown at the foot of the diagram. Various speeds may be attained for the propeller shaft by means of the change of connections between the two turbine sets and the induction motor that is also mounted on the propeller shaft; the maximum speed, however, at full power is only half that of the steam turbine, and apart from the very large revolving weight of the armature, it is questionable if the rise in speed of the turbine is sufficient to warrant the extra outlay and the installation of electrical transmission, owing to the comparatively small amount of steam that would be saved by only raising the turbine speed to double that of the propeller when under full load and vessel speed.

Another application of electrical power transmission for marine propulsion was brought out a few years ago by two British engineers, and in this case the steam turbine formed the prime mover. A high-speed steam turbine was here arranged for driving a continuous-current dynamo which in turn drove a series-wound motor. The motor operated at slow speed, the idea being that an economy in steam would be made because of the high speed of the turbine and that a further economy would be made by means of running the propeller at a low, and therefore the most efficient, speed for the power that was delivered to the propeller shaft. Fig. 8 shows the arrangement. It will be noticed that six propellers might be used, and that the turbo-generators were to be driven by three sets of plant, the whole connected in series in order that as the propellers rose out of the water in rough weather, the work and therefore the current would be less, thus weakening the fields of the generators and in consequence automatically reducing the voltage, the generators being driven at a constant speed by the governed turbines. The port or starboard side motors could be reversed from the bridge by means of the two-way switches, and the motor, and therefore the vessel's, speed could be varied by means of regulation provided by connecting

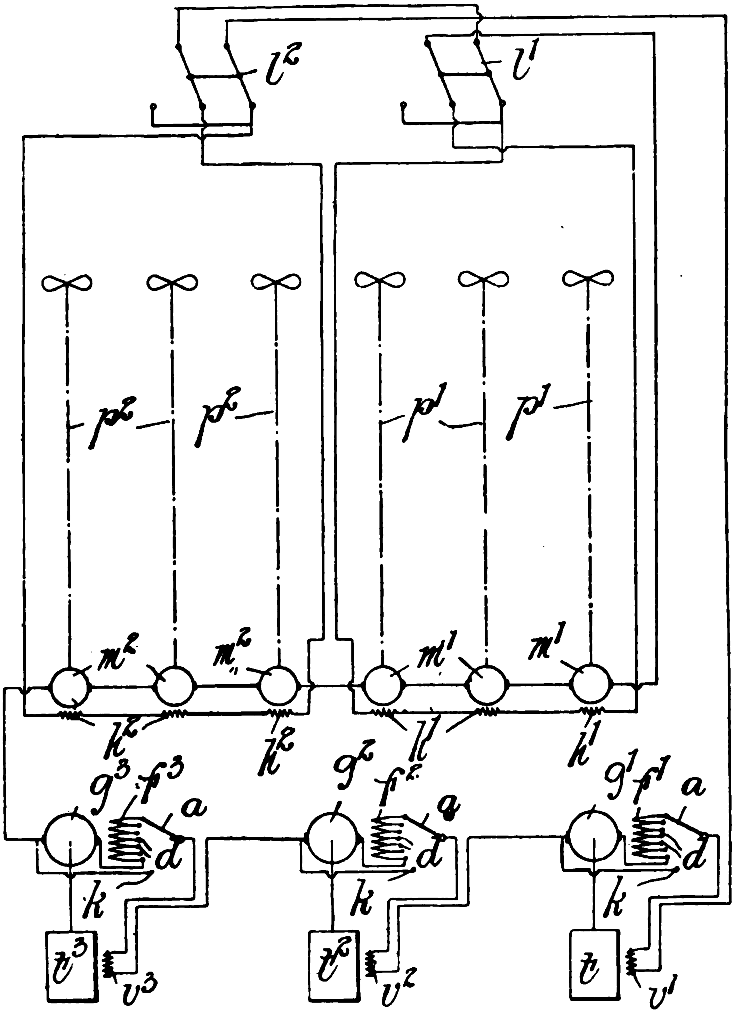

FIG. 8. "ALL-SERIES" DIRECT CURRENT ELECTRIC MARINE PROPULSION SYSTEM.

the fields with tappings as shown in the diagram. In the event of a low vessel speed being required one or two of the turbo-generators could be closed down and the whole of the work done by means of the remaining turbine set. It will be noticed that the circuit is never broken when regulating, and that solenoids are provided in order that as the current dropped, the steam would be cut off the turbines automatically. On going further into the question of marine propulsion, it was found that many difficulties in very large units would have to be surmounted before this method was possible for application to large ship propulsion, although it would be very suitable for small work.

The importance of providing a method whereby a slow vessel speed might be obtained for turbine-driven ships has attracted the attention of many people, and the methods that have from time to time been put forward are interesting. Amongst these might be mentioned a scheme that was suggested some years ago by a very large firm of electrical engineers on the Continent. Fig. 9 shows the arrangement. It will be noticed that three main turbines, T, are provided; these are in operation when the top vessel speed is required, and may be assisted by a still further turbo-generating set, G and T3, which supplies current to three motors mounted on the main turbine shafts marked E. In the event of a low vessel speed being required, the main turbines are run without steam, and the propeller shafts are then turned at slow speed by the above motors, supplied with current from the turbo-generator set G and T3, which is run at a high speed, being independent of the propeller shafts, which must run at a low speed. This arrangement is one of the many other attempts to get the right thing for securing increased economy in coal on turbine-driven vessels at low vessel speeds. the fault of turbines, as acknowledged generally, being

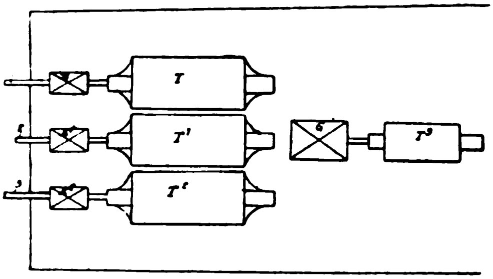

FIG. 9.

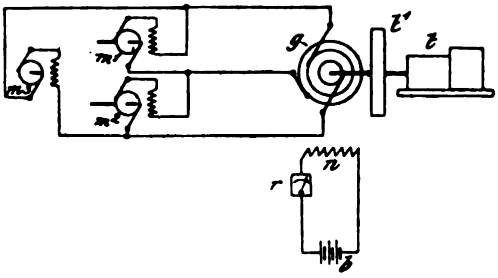

FIG. 10.

that if the turbine is run at a slow speed its steam efficiency is low per h.p. developed. There is no doubt that the above is a very practical application, but as the motors have to turn the rotors of the main turbines, whether the vessel is going "ahead" or "astern," and the period of these half-speed conditions is only a very small percentage of the time the vessel is under weigh, it is questionable as to whether the application was ever put into practice; further, as the main turbines have to run at a suitable slow speed to suit the propellers (being direct-coupled), it is very evident that no saving in steam would be made during the greater portion of the time that the vessel would be at sea, or that there is any very great advantage over the usual method, *i.e.*, that of carrying the ordinary reversing turbines as regards reduction of dead weight and first cost.

Another Continental firm have, however, gone a little further, as shown in Fig. 10, and it will be seen that in this case it is proposed to use a steam turbine to drive a three-phase alternator which supplies current to three

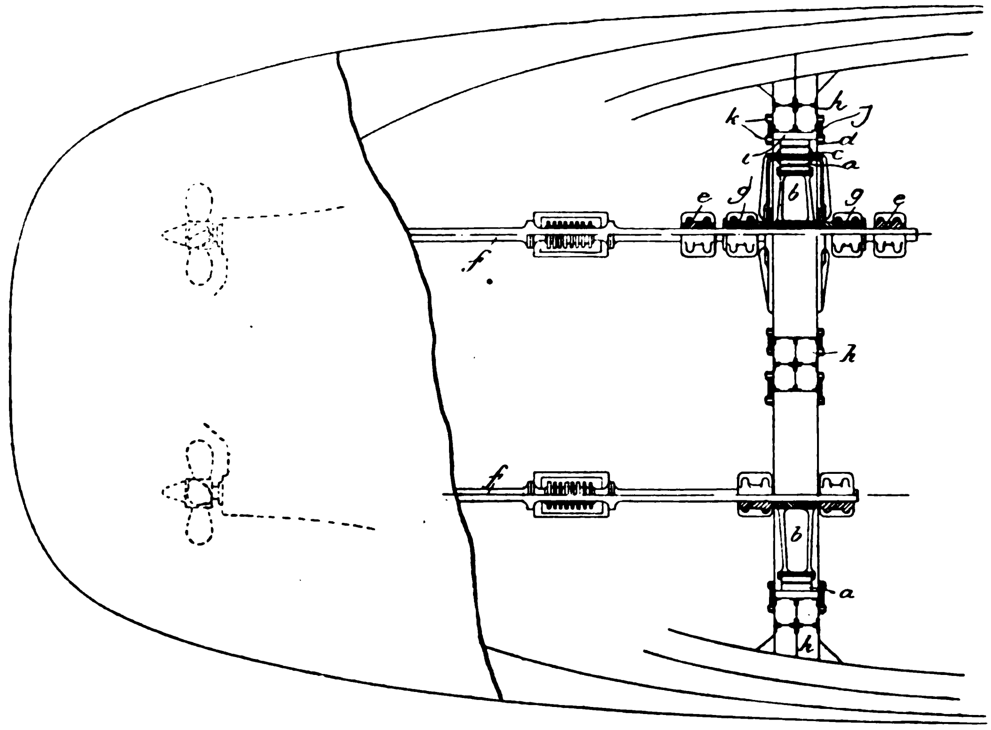

FIG. 11.

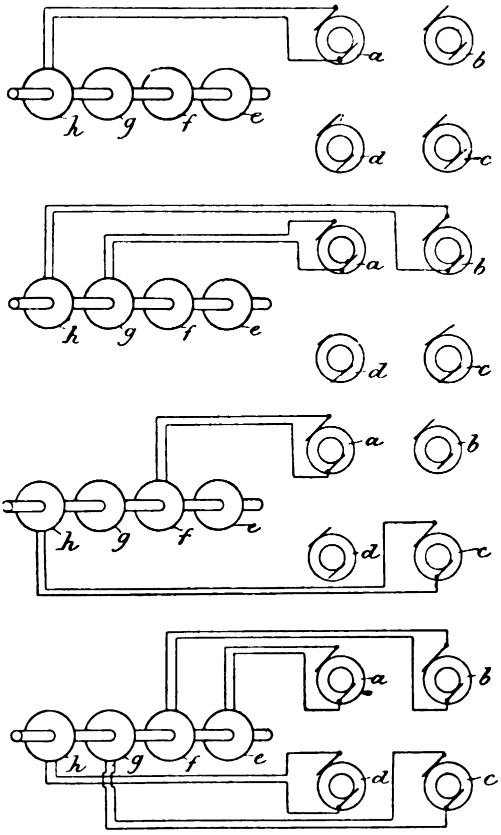

FIG. 12.

single-phase commutator-type motors coupled in mesh across the mains, and evidently engaging with three separate propeller shafts. This arrangement would no doubt work fairly well, but whether the weight of the single-phase motors and the fact that commutators are introduced on the main motors will outweigh the general advantages is a question remaining for practice to prove. Especially is its satisfactory working doubtful on occasions which require reversing under full vessel speed.

Another interesting system of electrical ship propulsion has also been brought out recently by a well-known electrical engineer in Scotland, and is shown diagrammatically in Fig. 11 as a twin screw lay-out. The motors are on the polyphase current principle, but their construction is modified in order that a variable speed may be got on the rotor of the motor; this is accomplished by means of an intermediate member or "spinner" as it is termed, which runs inside an outer stator. The main current is generated by turbo-alternators on board, and the speed variation at the motors is got by changes of connections and by means of a brake on the spinner. This system is most interestingly described in a recent issue of the Proceedings of the Institution of Engineers and Shipbuilders in Scotland, and has raised considerable interest in shipbuilding circles; it has been brought out by an engineer who, like the author, has been investigating this most interesting problem of high-speed steam turbine application in conjunction with electrical power transmission for main marine propulsion and speed regulation for some years.

A further system evolved by the same inventor is illustrated in Fig. 12. In this method a high-speed steam turbine is suggested to take advantage of the high steam economy that is to be obtained by running the turbo-alternator at its most economical speed for a given power, and in this case it is proposed to use for propelling the vessel four generators each wound for frequencies of, say, 20, 30, 40, and 60 periods, and on one common shaft to mount the rotors of four separate and distinct induction motors. Each motor is arranged with a certain different number of poles, so that by putting one of the above alternators on to the particular motor which is arranged with the most suitable number of poles to give the required speed, the shaft may be driven at 100r.p.m., 150r.p.m., 200r.p.m., or 300r.p.m. When the full speed is arranged for, the connections are such that the whole of the plant is at work, each generator coupled to its most suitable motor, to give the desired speed of, say, 300r.p.m., while the turbines may be running at, say, 1200r.p.m., thus providing in this case an equivalent gear reduction of no less than four to one. There is no doubt that working under these conditions, there would be a very large saving in coal per shaft horse-

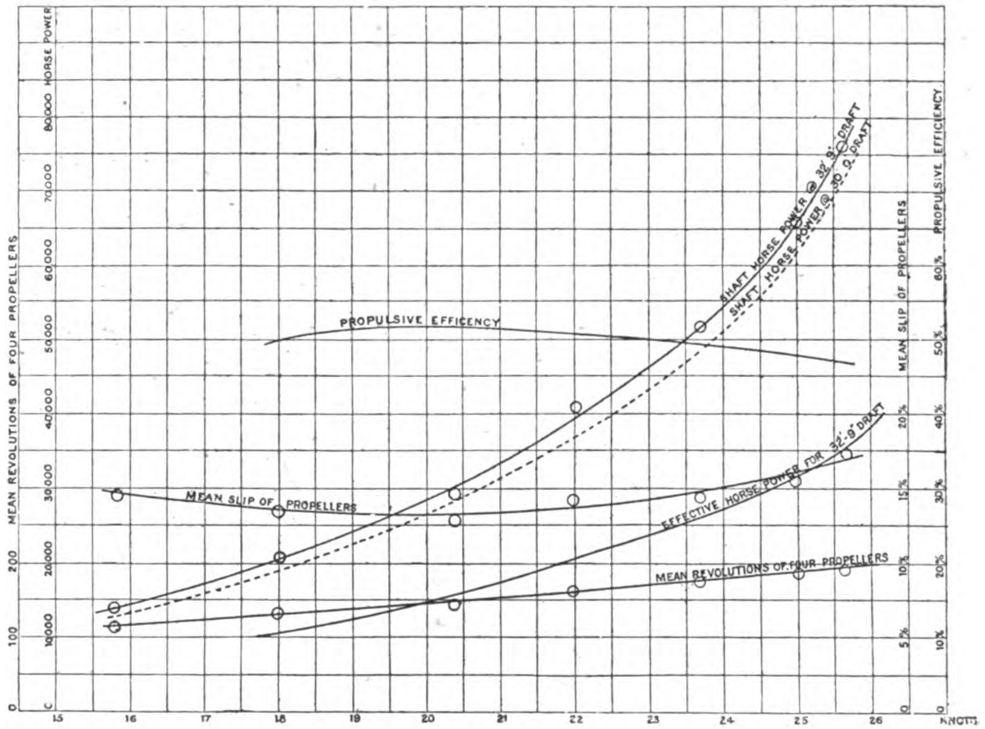

FIG. 13. CURVES SHOWING HORSE-POWER, PROPULSIVE EFFICIENCY, AND PROPELLER SPEED OF THE "LUSITANIA."

power delivered to the propellers, even after allowing for the electrical losses in the light high-speed generators and comparatively slow-speed motors. It can be said that this system of arranging the driving of turbine-driven ships should receive the very close attention of ship-owners, builders, and all those interested in the economical transportation of passengers and freight, and that it is decidedly a step in the right direction for the electrical propulsion of ships.

Having now given a few illustrations as to the progress that has been made, it will not be out of place here to refer to some of the conditions that have to be dealt with when designing an electrical power transmission plant for main marine propulsion. In connection with the driving of ships by means of high-speed steam turbines, it must be borne in mind that the object is to *save coal*, and therefore the best economy can only be attained by running the turbine at its most efficient speed. There is thus necessary a fixed maximum turbine speed most suitable, taking all other factors into consideration, such as the number of poles of the generator and motors respectively, and also that a set of efficient speeds must also be given to the propellers for slowing the vessel in case of fog, &c. At the same time one must bear in mind that at low vessel speeds it is essential to have the highest possible economy in steam, and this is best arranged for by so adjusting the ratio of the speed and number of poles of the generators that at half vessel speed one or several of the turbo-generators may be closed down, and only those turbines run which are essential to generate the amount of electrical power required by the motors when driving the propellers at a reduced speed; it must also be observed that the power goes up considerably with the vessel velocity. It is interesting to note here what takes place in ship propulsion: in order to move a ship, the resistance must be overcome, and when the propellers are started up

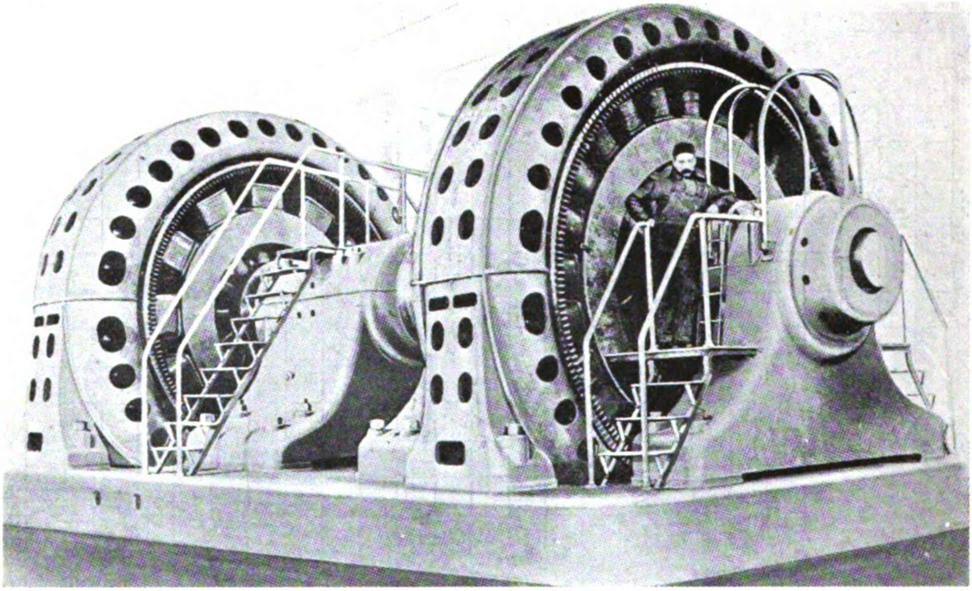

FIG. 14. PROBABLY THE LARGEST ELECTRIC MOTOR IN THE WORLD DRIVING A GENERATOR. MOTOR, 8000B.H.P. THE TOTAL POWER OF THE ABOVE SET BOTH WORKING AS MOTORS WOULD EQUAL 16,000H.P., OR EQUIVALENT TO THE POWER OF ONE SHAFT OF THE "LUSITANIA." WEIGHT OF THE TWO MOTORS ABOUT 170 TONS. ONE LOW-PRESSURE TURBINE OF THE "LUSITANIA" WEIGHS OVER 500 TONS.

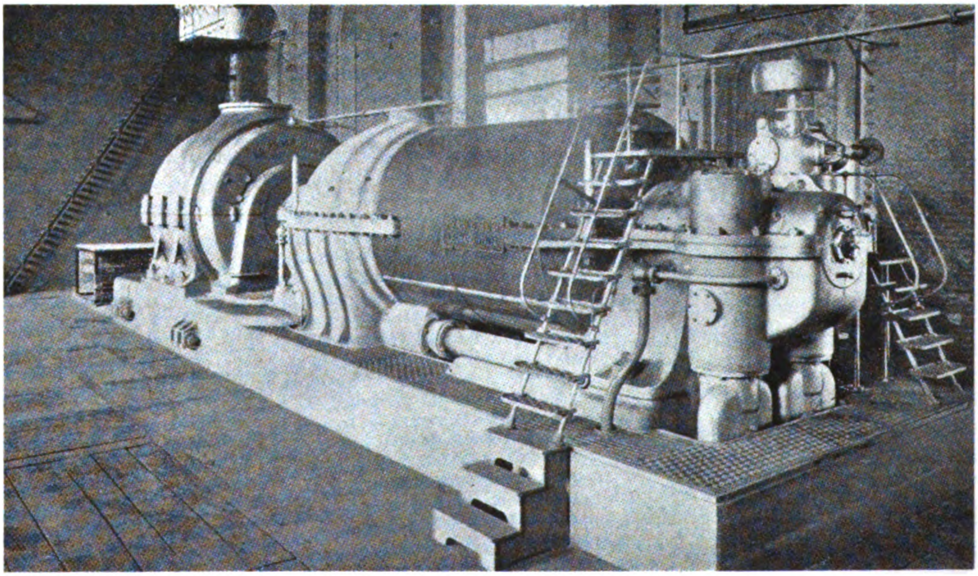

FIG. 15. 12,000H.P. TURBO-ALTERNATOR 750R.P.M. TOTAL WEIGHT OF GENERATOR, 73½ TONS; STEAM CONSUMPTION, 13.86LB. PER KW. HOUR.

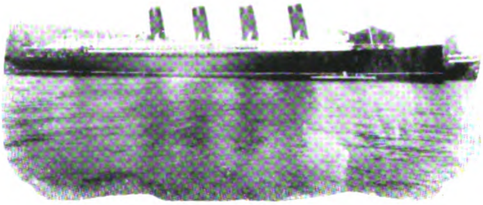

Fig. 16. The "Mauretania," showing "Kitten" "Turbinia" alongside.

they revolve for a short time before there is any appreciable headway or movement imparted to the ship. The power which has been thus expended is utilised to overcome the inertia of the vessel weight; when the inertia has been overcome the power is utilised in overcoming the consequent resistance of water and air to the moving vessel, and in accelerating the speed of the ship; as the speed increases the resistance increases and there comes a time when all the power is used for overcoming the resistance, and there is none required for increasing the vessel speed; the ship then moves along at an approximately constant speed. The resistance offered to a ship's motion in smooth water, may be divided into say three elements, viz., frictional resistance of the skin, eddy-making resistance, wave-making resistance. Frictional resistance is by far the most important; the amount of friction between the immersed skin and the water depends upon the area and length of the immersed surface, upon the roughness of same, and also upon the speed. (A foul bottom causes a considerable increase in resistance and consequent reduction in vessel speed, with a given power, and a ship's bottom and propeller blades should always be kept as clean as possible.) Eddy-making resistance is usually small, and is caused by the form of the stern, &c., and by the churning of the propellers. The amount of resistance due to wave-making depends upon the form of the ship: at the bows of all ships some waves are made, and if they pass away from the ship without producing a corresponding reaction under the stern, the energy used in forming the waves is wasted. Wind and waves at sea also cause the resistance to be increased, but the resistance from these is difficult to estimate; the larger and longer the ship the less the wind and waves affect its progress, as may be seen by the regularity with which our large ocean-going steamships make their voyages to and fro under varying conditions of wind and seas. Experimental data go to show that, within ordinary limits, the resistance to propulsion varies as the square of the vessel speed, and that the power required to overcome the resistance varies as the cube of the vessel speed; in other words, if a ship has a certain resistance

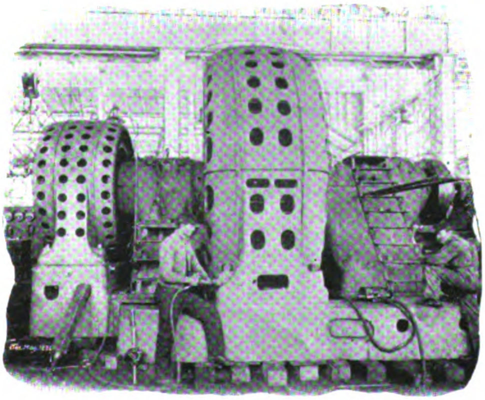

Fig. 17. An 8000B.H.P. Electric Motor.

Fig. 18. The "Mauretania."

at a given speed, the resistance will be four times as much if the speed of the vessel is doubled, *and the necessary horse-power will be approximately eight times as much.*

By considering the above laws and the various resistances there have been produced many formulæ for finding the power necessary for a given vessel speed, but these formulæ are of little value, however, unless the designer knows all the data of similar form, size, and speed.

The most economical speed is the speed at which the vessel can proceed a given distance with the least consumption of coal; or it is the speed at which the coal burnt per knot is the least. In general, however, if the vessel speed is reduced the expenditure in coal is also reduced for the above reason, that the horse-power is less. This reduction, however, only continues until a certain vessel speed is reached, after which the coal consumption rises per h.p. developed as the speed diminishes. There is no way to calculate the speed at which this change occurs; it can only be found by trial. The ship is run at various speeds and the engines carefully tested; the most economical speed then can be found by dividing the coal consumption per hour by the speed in knots, the lowest value shows the most economical speed at which to run the vessel generally.

In considering the best means of propelling a vessel, not the least important thing is the size and speed of the propellers that are to be used, and some of the interesting factors that have to be considered very closely are the following:

Above a certain revolution speed a propeller of a given diameter, pitch ratio, and area ratio, rapidly loses in propulsive efficiency (cavitation sets in and reduces the effective thrust). Cavitation is formed by the ineffectiveness of the atmospheric pressure to press up the water at the back of the blades of the propeller fast enough to allow of effective thrust, and usually occurs at high-revolution speeds and at high blade pressures per square inch of blade surface. The slip ratio there-

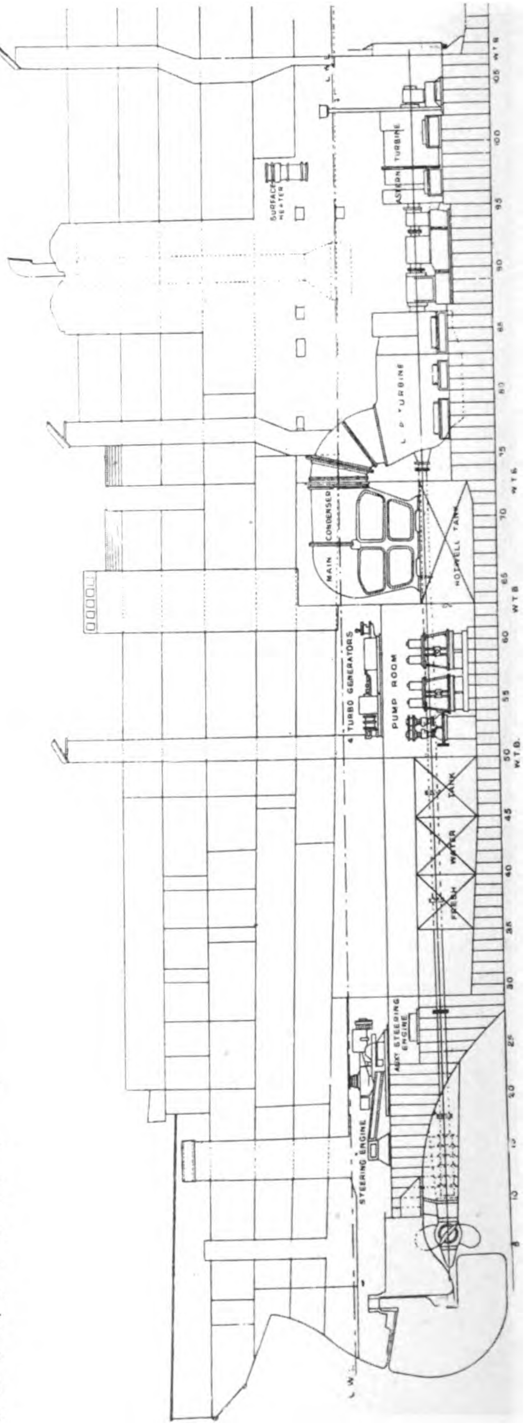

FIG. 19. SECTIONAL SIDE ELEVATION OF THE ENGINE ROOM OF THE "MAURETANIA." NOTE THE LARGE SPACE OCCUPIED.

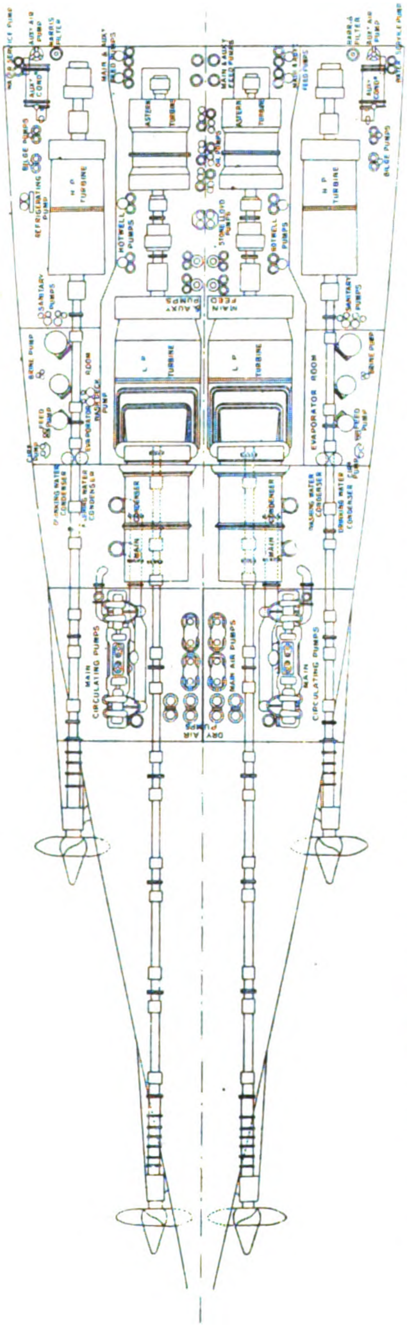

FIG. 20. PLAN OF TURBO-ENGINE ROOM OF THE "MAURETANIA," SHOWING HIGH PRESSURE, LOW PRESSURE, AND REVERSING TURBINES.

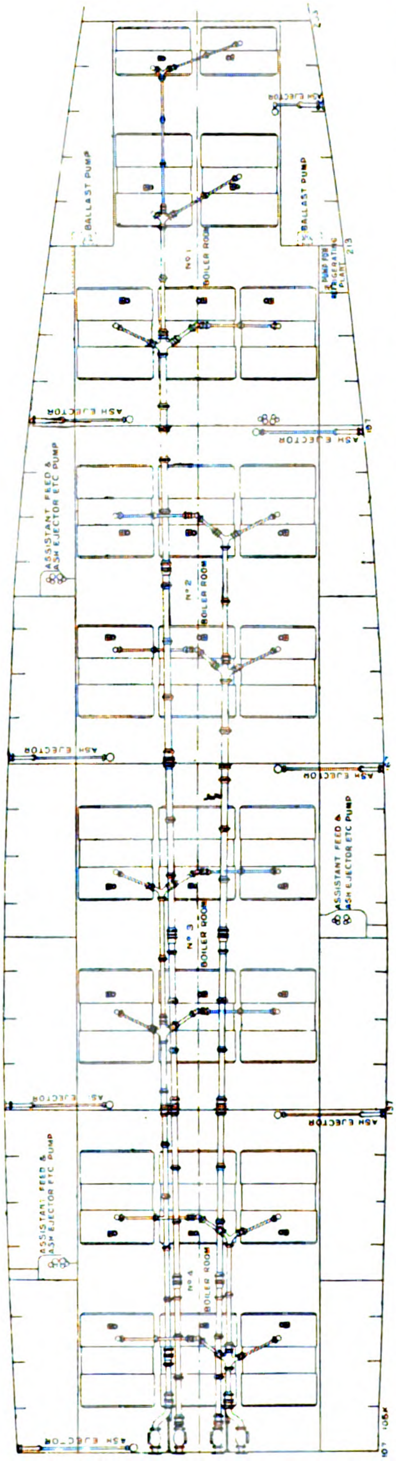

FIG. 21. THE BOILERS OF THE "MAURETANIA," CONSISTING OF 192 FURNACES, 23 DOUBLE-ENDED AND 2 SINGLE-ENDED BOILERS FOR TURBINE PROPULSION. FOR EQUIVALENT ELECTRIC MARINE PROPULSION ONLY 18 DOUBLE-ENDED BOILERS ARE NECESSARY.

fore increases, which produces a correspondingly reduced propeller efficiency. Propellers of small diameter at high speed and pressure possess the disadvantage of losing in propulsive efficiency, especially against head seas and winds, which again results in the slip ratio increasing, as may be observed from the manner in which direct-coupled steam-turbine vessels with high-speed propellers fall away from the trial-run speeds when at sea.

The highest propulsive efficiency is to be got from slow-speed large-surface blade propellers, and this is very evident in some of the very fine slow-speed reciprocating-engined ships, and is no doubt one of the reasons why that eminent authority, Dr. Caird, stated recently that had the *Lusitania* been fitted with reciprocating engines at 80r.p.m. instead of steam turbines at 186r.p.m., only 52830h.p. would have been necessary, instead of the 65,500h.p. at present required to propel the vessel at 25 knots. In the method used at present the propulsive efficiency is only 48.4 per cent., while in the case of slow propellers with the reciprocating-engined boat the efficiency would be more nearly 60 per cent., and the slip, instead of being 15.5 per cent., would be more like 9.5 per cent.

By the above it will be seen how the most efficient speed of the propeller materially affects the horse-power necessary to propel a given vessel, and it will now be interesting to note the effect on the design and construction of the, say, prime-mover that is to drive same. The steam turbine is naturally a high-speed power producer, and great difficulties have to be faced in satisfactorily applying the same to the direct-coupled method of ship propulsion, especially when it must be considered in the light of a "commercially" good proposition; that is, as a dividend-earner.

The theoretical best efficiency of the steam turbine is attained when the linear velocity of the rotating blades is equal to one-half that of the velocity of the steam impinging upon those blades, and as this figure is very high there remain but two alternative methods of obtaining the conditions that the best efficiency would require. The first of these two is to arrange the revolution speed so high as to enable the blades to receive the steam under the above conditions.

The other alternative is to reduce the speed rotation of the turbine by increasing its diameter in equal ratio to the reduction of the rotative speed, which, of course, has the disadvantage of increasing the weight and steam leakage of the turbines of a given horse-power, and also the cost of same. At the same time the latter method does not

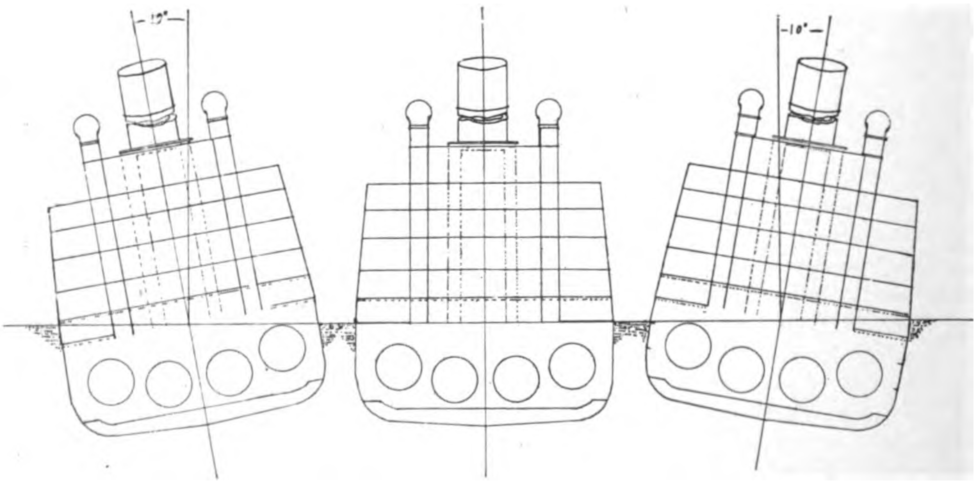

FIG 22. SHOWING EFFECT OF HEELING 10DEG. AND UNEQUAL IMMERSION OF PROPELLERS. WITH A.C. MOTORS RACING IS AVOIDED AND IMPROVED PROPULSION EFFICIENCY IS ATTAINED.

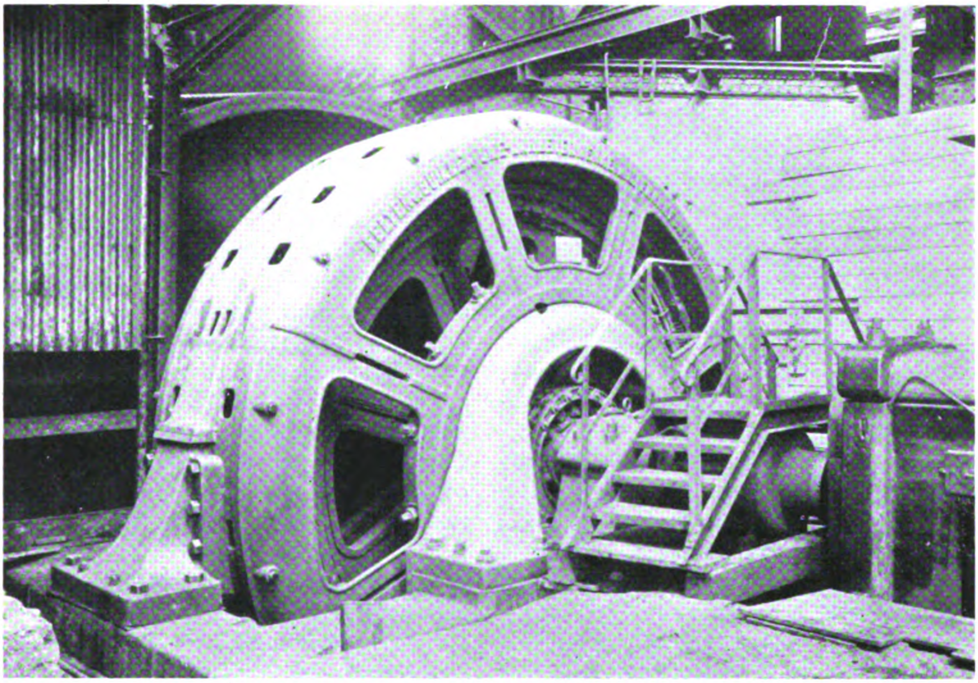

FIG. 23. A 2000B.H.P. INDUCTION MOTOR, SPEED 100R.P.M.; EFFICIENCY, 94 PER CENT.; WEIGHT ABOUT 100 TONS.

allow of the very necessary use of superheated steam to the extent that is possible in the high-speed type, as, to allow for the rotor and case expansion, a certain clearance has to be allowed for between the tips of the rotor blades and the inside surface of the casing, also between the tips of casing blades and the outside surface of the rotor drums. The consequent leakage, of course, works out as a certain percentage of steam over the blade tips, no useful work being done by the steam thus passing through, and it is calculated that if the loss is, say, 3 per cent. when the revolutions are 600 per minute, then the corresponding leakage at 200r.p.m. will be approximately 27 per cent., as the percentage loss varies as the square of the revolutions, or, which is the same thing, as the square of the rotor diameter. So that, allowing for the increased expansion due to larger diameter drums, the loss increases by the square of the diameter, or in other words by the extra area open to leakage.

It will therefore be very evident why it is thought advisable in many directions in direct-coupled steam-turbine-driven vessels to sacrifice a certain amount of propeller efficiency in order to raise the speed and therefore the steam efficiency of the turbine, and this accounts to a great extent for the high slip ratio noticeable in many turbine steamers afloat to-day; for the sake of reducing the boiler capacity and the weight of the same, it is found absolutely necessary to drop some of the possible propeller efficiency by raising the speed of the propeller to suit the steam turbine efficiency, and even then the turbine is not run at its most efficient speed, when its weight is taken into consideration. Hence it will be seen that although the turbine is better in steam efficiency the propeller would be better in propulsive efficiency at a lower speed. A compromise has therefore to be arranged to produce the highest (under the circumstances) combined efficiency of the turbine and propellers: that accounts for the misleading statements so often made as

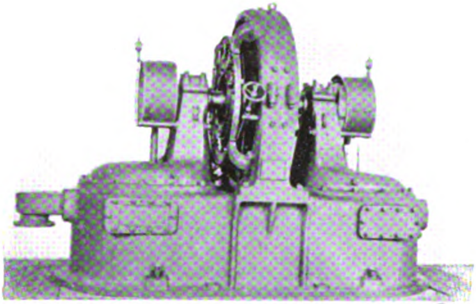

FIG. 24. ELECTRICALLY-DRIVEN AIR PUMP FOR 12,000H.P. TURBO-ALTERNATOR.

regards the *steam used per shaft horse-power*, and in some cases it really appears very low; but if the speed of the propellers be looked into, it becomes very evident that the propulsive efficiency is low: the power that is delivered by the turbine to the propellers is high in comparison to that power which would only be necessary for the same vessel speed and displacement if a slower speed propeller had been used, and as a consequence the cost in coal per passenger or cargo-ton mile is naturally higher. Direct-coupled turbine steamers are not very efficient in the all-important matter of quick stopping and reversing, which is an essential property to be possessed of and is particularly indispensable in the cases of battleships, cruisers, and other war vessels, cross-Channel boats and the like. It is said that owing to the lack of reversing power it is necessary to take the steam off the "ahead" turbines some considerable time before reaching the landing stage, and that the time gained in a quick vessel speed is to a great extent taken up at landing, so that the average time of the trip is longer (across Channel) than it would have been had the turbine vessels had the same power on reverse that reciprocating-engined ships have.

It should also be borne in mind that the sudden reversal of the steam turbines is very severe on the turbine and steam consumption, as excessive vibrations are said to be set up by the change of rotation, and this is especially so when the reversing has to be carried out (say to avoid a possible collision) when the vessel speed is high and the positive torque at the propeller is almost at the maximum.

A further point, and of considerable importance from the "commercial" aspect, is the fact that when direct-coupled turbine steamers are slowed down owing to fog or other reasons, or are proceeding at a slow vessel speed such as when manœuvring in or out of harbour, &c., the steam consumption per shaft h.p. developed is very high, and is a serious matter to contend with, especially in the case of cargo boats that travel to all parts of the world, meeting with all conditions of weather, &c. A case in point is given by Mr. Thomas Bell, in his very interesting paper on the steam trials of the *Lusitania* read before the Institution of Naval Architects recently, in which he stated that when steaming at 25.4 knots the steam consumption by the main turbines alone, without auxiliaries, was 12.77lb. per shaft h.p. hour, and that when the vessel was slowed down to 15.77 knots, the steam consumption was no less than 21.23lb. per shaft h.p. hour developed at that lower vessel speed, showing conclusively that by slowing the vessel speed 38 per cent. the steam consumption rose to 65 per cent. more per h.p. developed than that which was required by the same turbines, when running at a higher speed, at the higher vessel speed. It is also stated that the *Dreadnought* and also the German cruiser *Luebeck* are very sluggish in manœuvring qualifications, probably for the above reasons.

Having described some of the general conditions to be met with, we will now return to the subject of this article, and it will possibly be more than of passing interest to note what immense advantages the electrical transmission of power has in store for the progressive steamship owner and builder. By this means it is possible to get the ideal and efficient slow-speed propeller and also to run the steam turbine (or other prime mover) at its most economical speed, using steam to the best advantage, reducing the capacity of the boiler-room equipment and effecting a corresponding considerable saving in the weight of the same. The boiler room weight is the heaviest item in any steam-ship, especially when taking into account the dead weight of the water in the boilers, condensers, &c., as it is quite evident that if we use less steam we shall require smaller condensers, &c., also a considerable reduction in the stokehold and bunker capacity; these reductions, together with the fact that we need not install the usual reversing turbines, &c., with all the cross-connecting steam pipes, valve gear, &c., mean that a very considerable saving in weight and first cost is well within the range of practical possibility as compared with the existing methods on direct-coupled steam turbines and reciprocating-engined ships.

As a comparison, for instance, we will take the *Saxonia*, which is one of the finest liners afloat, fitted with reciprocating engines, and is a twin-screw ship. According to published data this Cunarder has a boiler steam capacity of 132,600lb. per hour (according to the Report of the Committee on Naval Boilers), the total boiler-room equipment weighs 1000 tons; *i.e.*, she therefore gives an output per ton of boiler-room weight of 132.6lb. of steam per hour. The boilers were tested and found to give the very high evaporation of 11.3lb. of water per lb. of coal burnt (actual); the engines were indicated, and it was proved that she used the very low (for marine practice in this size engine) quantity of steam of 13.5lb. per indicated h.p. hour, which is considered in marine engineering circles as very good.

Dr. Bauer (an eminent authority) gives the weight of marine reciprocating engines of this type, including the propeller shafts and propellers, as 150lb. weight per indicated horse-power. Taking this into account the total weight of the *Saxonia's* engines, &c., is 658 tons. As the output of the boilers was 132,600lb. of steam per hour, the indicated horse-power was therefore 9822, or allowing a mechanical efficiency of the engines of 85 per cent., the brake horse-power on each port and starboard propeller shaft was 4175. The total weight of the boiler-room and engine-room equipment was 1658 tons. Taking the evaporation as equal to 11.3lb. of water per hour per pound of coal burnt as above, the total coal burnt per hour is therefore 11,734lb. or say 5½ tons.

We will now look into the question as to how an electrically-propelled *Saxonia* will show up as regards coal consumption (for the same b.h.p. produced), and also into the possibilities of reduced weight of propelling machinery (taking the boilers, &c., into account as well, as they have to be pushed along and fuel burnt to do so, &c.). Working backward from the motors, which would be of the three-phase squirrel-cage type, the brake horse-power of each would be 4175, at a speed of, say, about 97r.p.m.; the weight of these motors, shafts, and propellers would be (taking the weight as 90lb. per b.h.p.), say 336 tons. The electric power would be generated by two turbo-generators, each capable of giving 3265kw., running at a speed of 1300r.p.m., at, say, 200lb. steam pressure, with superheat of 150deg. Fah., and with a vacuum of 28in. at sea: on a trial run this would be considerably higher. These turbo-generators would under the above circumstances use, say, 14lb. of steam per kilowatt hour, and would weigh complete with condenser, steam and exhaust pipes, control gear, &c., say, 90lb. per kilowatt, or altogether 262 tons, making a total weight of engine-room equipment of 598 tons.

Now the above turbo-alternators would consume 14lb. of steam per kilowatt hour, therefore the total steam used would be 91,420lb., and taking the same evaporation as before per ton of boiler room weight, namely 132.6lb., makes the boiler-room equipment of the electrically-driven *Saxonia* only 690 tons.

The total weight of the whole boiler room and engine room plant will therefore be 1288 tons, and this, when compared with the existing reciprocating-engined ship weight, which is 1658 tons, shows a saving in the weight of the propelling plant, including boilers in both cases, of no less than 22.3 per cent.

The steam consumption at 14lb. per kilowatt hour (which can be guaranteed) is 91,420lb. with the turbo-electric plant, as against 132,600lb. at present with the reciprocating engines, and represents a steam saving of no less than 31.5 per cent. in favour of electric propulsion. Taking the evaporation of water per lb. of coal burnt as in the existing *Saxonia*, namely 11.3lb., the total amount of coal burnt to produce the same horse-power at the propellers would be 8091lb. per hour, or equal to say 3.6 tons; and taking the present consumption of coal as given by the above evaporation as equal to 5.25 tons, this is also equal to a saving in coal of 31.5 per cent.

The *Saxonia* runs to Boston from Liverpool, and does about 15 knots, taking about eight days for the voyage; she therefore has to load (approximately) 1008 tons of coal per single trip: but the electrically driven *Saxonia* would only have to load say 696 tons instead. As the coal cost is approximately 50 per cent. of the cost of working ships, this is not of the least importance to the ship-owner. The subject is of the utmost interest to the naval architect, as, taking the saving into account of the weight of propelling machinery, &c., and also the saving and consequent less tonnage of coal to be carried, the total less weight at starting the voyage will therefore be no less than 682 tons (not counting the fewer number of stokers and attendants required).

It should also be remembered that with a given cargo tonnage the reduced weight of the plant will have a considerable effect on the reduction of draught of the vessel. An important point in this last connection is that with reduction in draught we are providing the same shaft horse-power; it is obvious therefore that the vessel speed will consequently be higher for the above reduced coal and steam consumption, therefore the actual time taken by the vessel will be reduced, and the total consumption of coal for the voyage will therefore be actually less than that given above.

The *Saxonia* is one of the finest examples of reciprocating-engine-driven vessels afloat, and is recognised as one of the easiest vessels to drive. It is of interest to note that Dr. Caird quoted in a discussion on marine propulsion recently at the Institution of Engineers and Shipbuilders in Scotland, that the tests of the 4096kw. turbo-alternators at the large generating station at "Carville" in Newcastle showed a consumption of 13.8lb. of steam per hour, at a steam pressure of 200lb., with a superheat of 108deg. Fah. and 29in. vacuum, which goes to show that the allowance that has been made in this case is well within the bounds of practice.

And there is no reason why the electrical transmission of power for main marine propulsion should not be brought forward and raised to a very strong and impregnable position.

In these days when large sums of money are being expended on increasing the steaming radius and fighting capacity of battleships, cruisers, &c., it is really surprising that more practical attention has not been paid to the almost certain fact that the electrical transmission of power system will become the final link to bring the steam turbine and the internal combustion engine to a real point of economy; and it well merits the serious attention of naval architects and designers of ships of war since economy in coal bears a highly important relation to the possibility of carrying heavier armour, &c., for a given displacement.

As a fair comparison we will take the case of the *Dreadnought*, of which the published trial figures state that the steam consumption was 14lb. per shaft or brake horse-power hour (not including auxiliaries), and that the total power at the top vessel speed was 28,000b.h.p. on four shafts, say, 7000b.h.p. on each. Each shaft and propeller ran at an average speed of 300r.p.m., and taking the above figures it shows that the boilers generated (for the main propulsion only) 392,000lb. of steam per hour, and the evaporation at the trials worked out at about

10lb. per pound of coal burnt. The vessel was tried under service conditions, and the important point is that the coal consumption equalled 1.4lb. per shaft horse-power hour developed; that is to say, equal to a coal consumption per day of twenty-four hours of 420 tons. On the *Dreadnought* there are ten turbines installed: four for the full speed ahead; four to put in series with the above when going at cruising speeds of about ½ or ⅝ full vessel speed, thus taking the expansion further, and making this cruising speed as far as possible economical; there are also two turbines for reversing, together with all the cross-connecting steam pipes and valves, &c.

It is interesting to compare with this what might have been done in an electrically-driven *Dreadnought*. To generate the said 28,000 shaft horse-power we will provide, say, four 32-pole 7000b.h.p. induction motors connected to the above four shafts, in this case running at, say, the same speed—namely, 300r.p.m. Taking the mechanical efficiency of these motors into consideration, which at full load would be, say, 95 per cent., the current would be generated by three 7600kw. turbo-generating sets, each running at a speed of 1000r.p.m., and using steam at 200lb. pressure, with superheat at 150deg. Fah. and with 28in. vacuum, the steam consumption per kilowatt hour will be about 13lb. Therefore at full load and top vessel speed the total steam consumption for the main propulsion would be only 284,700lb. per hour, or equal to a fuel consumption for a 24-hour run of 305 tons—a saving in coal consumption of no less than 27 per cent. per shaft horse-power developed as compared with propulsion by steam turbines alone. That is to say, taking a full speed run for six days, the total saving in coal burnt would equal 690 tons, there would be this less weight of coal to be carried, and a further corresponding saving of the coal that would be required for the extra power to convey this extra weight at the high vessel speed.

The effect on draught, cost, steaming radius, vessel speed, &c., by such a saving in coal and steam would be enormous, and it goes without saying that such a saving of 27 per cent. in coal reflects itself on the cost of the plant, and also the operating expense, maintenance, &c., in the following items at least: coal bunkers, fuel, boilers, feed-pumps, feed-pipes, steam pipes, exhaust pipes, condensers, funnels (a very important item), draught fans, air and circulating pumps, as well as the many other conditions that make up the steam generating plant and equipment of a modern battleship.

Nor would there only be *three* turbines on board in the place of ten, but the induction motors would run just as efficiently in either direction, so that there would be no necessity to install the usual reversing turbines, which are only mounted on two of the four propeller shafts. It is obvious that the full power may be given on all the propeller shafts, so that the possibility of stopping the vessel in short time, in case of collision, manœuvring, &c., is one of the most valuable advantages secured from a combatant point of view for turning tactics, manœuvres, &c.; further, for the cruising speeds that are necessary (as a warship rarely makes a long distance trip in the ordinary way at top vessel speed) a very great economy is to be made by the fact that two of the above turbo-alternators may be closed down, and the work of propulsion done very efficiently by the remaining one, so that instead of slowing down the turbines, as is done at present, the turbine generator would still run at the same speed, namely 1000r.p.m., but the motors, and therefore the propellers, would only run at just a little above half top vessel speed; as the slip ratio increases slightly with the drop of vessel speed, with a given pitch propeller; it is therefore quite obvious that two-thirds of the boilers might be closed down, and the very large losses at sea due to radiation effects, and also the dead weight water in the boilers saved when making an extended voyage under cruising speeds, further reducing the draught, and making the possibility of a larger mileage to be covered with a given amount of coal.

Taking into consideration that the induction motors would be almost right back at the stern, the propeller shafts would be shorter than is now the practice, and this would obviously minimise the friction and out-of-line losses of long rapidly revolving shafting in rough weather, especially under severe pitching conditions, when the hull is constantly under more or less severe bending stresses, and this again tending to decrease of transmission losses from the comparative prime-movers in each case. Consequently shaft tunnels will be conspicuous by absence, and naval architects would have better facilities of "trimming" their ships, since the generating plant could be in any part of the vessel as might be convenient and for buoyancy sake desirable, and in some cases make a considerable reduction in the size and dead weight of ballast tanks required, which have to be pushed along; and it is well within the range of possibility that the hull design would consequently be reduced for a given safety factor in strength and weight.

Considerable interest has been aroused recently by the speed and travelling convenience of the modern cross-Channel turbine-driven steamers, and some reference to these interesting vessels is not out of place in these notes, but as to whether these most elaborate vessels can be seriously looked on as "commercial" successes remains for time to prove. The following figures may be of interest because of the approximately equal displacement of two vessels, one fitted with reciprocating engines, and the other fitted with steam turbines.

	NANTUCKET.	GOVERNOR COBB
Date of test	Feb. 7, 1904	April 18, 1907
Duration of test—boiler ..	20½ hrs.	8 hrs.
Duration of test—engine ..	20½ hrs.	4 hrs.
Boiler pressure (average gauge)	147·3lb.	128lb.
Quality of steam (sampled at drip)	98·8	97·3
Barometer	14·7lb.	14·7lb.
Temperature of air pump discharge	—	110° F.
Temperature of feed water	209·4° F.	213° F.
Kind of coal used	Georges Creek	Cape Breton
Moisture in coal	2%	1·9%
Ash and clinker in coal ..	7·6%	6·8%
Draught at blowers.. ..	Natural	2·1 inches
Number of boilers (single-ended Scotch)	4	6
Total grate surface	320 sq. ft.	323 sq. ft.
Total heating surface, approximately .. .	10,150 sq. ft.	12,000 sq. ft.
Ratio, heating to grate ..	31·7	37·2
Coal fired per hour	5,135lb.	8,050lb.
Water fed per hour (average during engine test) .	45,844lb.	85,710lb.
Coal burned per square foot grate surface	16lb.	24·64lb.
Maximum revolutions ..	—	p. 475, s. 460 c. 440
Corresponding total shaft horse-power	—	4,100
Average revolutions ..	74.05	447
Average total horse-power .	2,362	3,747
Steam for auxiliaries ..	—	38,360lb.
Steam per I.H.P. per hour, total	19·41lb.	—
Steam per brake horse-power per hour, total ..	—	22·87lb.
Propelling machinery only	—	19·74lb.
Speed (average) in knots ..	15·00	17·21
Type of engine	Reciprocating	Turbine
Vacuum in inches	25	27

DIMENSIONS.

Length between perpendiculars	274ft.	290ft.
Beam moulded	42ft.	51ft.
Draught	15ft.	14ft.
Displacement..	2,700 tons.	—

It will be noted that in the reciprocating-engined ship the steam used, including auxiliaries, was 19.41lb. per i.h.p. hour, and this, allowing a mechanical efficiency of 85 per cent., gives a steam consumption of 22.8lb. per shaft horse-power hour; in the turbine-driven ship the steam consumption is, including auxiliaries, 22.87lb. per shaft horse power, but attention should be drawn to the fact that the speed of the propellers, and, therefore, the propulsive efficiency, was vastly different in each case, accounting for the extra horse-power provided for in the turbine vessel, as the increase in speed of the latter is so small in proportion to the increased horse-power.

A great amount of interest and discussion took place in the United States at the Society of Naval Architects, before whom the particulars were presented, and they were later vouched for by one of the most eminent authorities in American shipbuilding circles, who stated that "there was every reason to believe that the water meter used in determining the feed water gave very accurate results. The meter was calibrated by the manufacturers before leaving their works, and was calibrated at the Institute of Technology in the department of Naval Architecture after the test was made."

He further pointed out that it was interesting to note that the coefficients determined by the experiments differ from those as given by the manufacturers by less than half of one per cent. The fact that a curve of meter readings, plotted at ten-minute intervals, followed exactly the fluctuations of power was a pretty strong indication that the readings of the meter were not sensibly in error.

Taking the steam consumption in this turbine-driven ship, it is interesting to compare it with the possibilities of an electrically-driven cross-Channel vessel of the same horse-power with the propellers running at the same speed; though in really designing such a vessel equipment a slower speed for the propellers would naturally be taken.

Three 1250b.h.p. 20-pole squirrel-cage induction motors, running at a speed of 447r.p.m., with a mechanical efficiency of 93 per cent., requiring 3020kw., this generated in two turbo-alternators, each giving 1510kw., each running at a speed of about 1500r.p.m., and supplied with steam of a pressure of 160lb. per square inch, with a superheat of 150deg. F, and a vacuum of 28in., would consume, guaranteed, 16lb. of steam per kw.-hour, which is equal to a consumption of steam per shaft horse-power hour on the motors of 12.8lb., or a saving of no less than 35 per cent. in steam for the same shaft horse-power. The possibilities of the application of electrical power transmission for the propulsion of cross-Channel boats should therefore be very encouraging, and when our railway companies wake up to the fact that such a saving is possible, it is to be hoped that a vessel may in the near future be equipped. It is certain that the owners would find that such a vessel would be a good dividend-earner, which is more than can be said for the majority of the direct-coupled steam turbine-driven vessels running at present, and this question would be more than appreciated if, when the various papers are read before the engineering societies on the matter of the "commercial" application of the direct-coupled marine steam turbine, the authors were to state the actual steam used by the turbines per shaft horse-power hour; if the coal is quoted only, the possible high evaporative efficiency of the boilers is not taken into account, and the turbine given the credit of the low coal consumption, very often quoted per shaft horse-power developed, which is very misleading, as the "commercial" efficiency of any vessel should be quoted in the lines of the amount of coal burnt per ton of displacement per mile, or ton of passengers or freight carried a given distance; it will be seen that the above comparison points out that even at the same propeller speed the electrically-driven vessel only uses 1.28lb. of coal, as against the direct-coupled turbine ship (without auxiliaries), which uses 1.974lb. — when taking the evaporative efficiency of the boilers as equal in both cases to 10lb. of water to 1lb. of coal burnt per shaft horse-power hour.

We have now considered a first-class reciprocating-engine vessel, the *Saxonia*; a latest type of battleship, the *Dreadnought*; and a fairly recent small power cross-Channel boat, the *Governor Cobb*, and it is very evident that a considerable saving in coal, etc., may be made in each case for a given vessel speed and displacement.

The fact that direct-coupled steam turbines were adopted for propelling those enormous leviathans the *Lusitania* and the

Mauretania naturally will lead many to think as to what electrical transmission and speed regulation would have been able to accomplish in vessels of this power and dimensions. They are approximately twin vessels; the *Mauretania* is, however, the larger of the two, and apparently the most efficient, judging by published figures. It was stated that the steam used per shaft horse-power hour on the *Lusitania* trials was 12·77lb., while in the published figures, as given recently at the Society of Arts, it was stated that the *Mauretania* only used 11.5lb. per shaft horse-power. Taking this power to be 68,000h.p., that is, equal to 17,000h.p. on each of the four shafts, the consequent steam consumption being, say, 782,000lb. per hour, taking the evaporative efficiency of the boilers to be equal to those of the *Lusitania*, *i.e.*, 10.2lb. of water per lb. of coal burnt, the total coal required per hour amounts to 34.25 tons (for propulsion only); taking the *Saxonia* boilers giving off 132.6lb. of steam per hour per ton of boiler-room weight as a fair average, then the weight of the *Mauretania's* boiler-room equipment is equal to 5897.4 tons. It has been given out that the weight of the turbine and propelling machinery of turbine-engined ships is 7 per cent. less weight per shaft horse-power than for a corresponding power in the reciprocating-engined ships. Therefore taking Dr. Bauer (an eminent authority) who gives the weight of reciprocating engine room and propelling machinery as equal to 150lb. per i.h.p., and taking the mechanical efficiency of the engines at 85 per cent. we have as the weight of plant 177lb. per shaft h.p. developed; allowing the above 7 per cent. lighter per shaft h.p., we get in the turbine ships a weight of engine-room equipment of 165lb per shaft h.p. developed. That being so, the total weight of the *Mauretania's* engine-room equipment is approximately 5000 tons, therefore the total weight of the steam plant is 10,897 tons. The above very low steam consumption per shaft h.p., together with the evaporation as shown per lb. of coal burnt, means that the total coal consumption (for propulsion only) is equal to 34.2 tons per hour; or she would have to load, taking five days' steaming, 4134 tons for propulsion only.

Now, in the equipment of the electrically-driven *Mauretania* we shall require, say, eight squirrel cage induction motors, each capable of giving off 8500b.h.p. (two mounted on each of the four shafts); these, with a mechanical efficiency of 95 per cent. at full load and at a speed of 200r.p.m., would require 53,200kw. To supply this current we should take, say, four 13,300kw. turbo-alternators, running at a speed of, say, 800r.p.m., and on a steam pressure of 180lb. pressure, superheated by 150deg. F., and on a vacuum of 28in., the steam consumption would be 11lb. per kilowatt hour, and the total steam required would be 585,200lb. per hour, or equal on the above evaporation to 25.7 tons of coal per hour, or a saving of no less than 25 per cent. in coal consumption for the same shaft horse-power developed.

As regards the weight of the necessary boilers, taking the same constant as above, namely 132.6lb. of steam per ton of boiler-room equipment, it would therefore be 4414 tons only.

The weight of the engine-room and propelling equipment would be as follows:

Four sets of motors and propeller shafts, propellers, &c., equalling 68,000h.p. at 70lb. per horse-power developed, gives a weight of 2125 tons.

Four turbo-generators (53,200kw.), with condensers, pipe-work, &c., at 70lb. per kw., equals 1663 tons.

Therefore the total weight of the propelling plant of an electrically-driven *Mauretania* would be approximately 8202 tons, as compared with the estimated 10,897 tons, or 24.5 per cent. less weight for the plant.

As she would only use for a five-day full-speed trip 3090 tons, she would therefore have to load 1044 tons less, or taking into consideration the saving in dead-weight of machinery, &c., and coal per trip, there would be a dead-weight saving of no fewer than 3739 tons, not taking into consideration the smaller amount of auxiliary machinery required, the less number of stokers and attendants necessary, &c. There is also no reason why the speed of an electrically driven *Mauretania's* propellers need exceed, say, 150r.p.m., which although tending to increase the weight of the motors (only) would give a much higher propulsive efficiency per horse-power delivered, thus increasing the vessel-speed or requiring less power for the same vessel-speed.

Probably the largest tonnage in vessels afloat is in that type of vessel usually called a "tramp," or a vessel that is a purely cargo-carrying one, and a reference to the power equipment of one of these ships is not without interest as to the possibilities of electrical power transmission application, especially bearing in mind that the direct-coupled steam turbine is not suitable for this kind of vessel, as the vessel-speed is too low, and also the fact that in many instances the above vessels have to run at an extraordinarily low speed, especially when coal is not to be obtained at some port abroad. In that case they generally slow down the engines, working them with a very expansive stroke, for the reason that the power is, say, at half-vessel speed, only perhaps one-fifth that at top-vessel speed (or even less); such facilities are appreciated in shipping circles, especially in certain cases as when time is not of the utmost importance. Not only would the direct-coupled turbine not be suitable for this class of vessel, but, if it were required to slow the vessel for any reason, as above explained, the steam consumption would be excessive, and the above operations could not be satisfactorily carried out.

The author recently had instructions to design a set of electrical-propelling machinery for one of these vessels, and the following particulars were given to him to work to for guidance:

339 × 46.2 × 22.5ft. draught.
Displacement 8010 tons.
Deadweight carrying capacity 5700 tons.
Block co-ef .796.
Speed 9.2 knots.
I.h.p. 1250 (single screw).
Coal consumption 20 tons per day of twenty-four hours.
Weight, hull and equipment 2000 tons.
Machinery, including boilers, &c., 300 tons.
Boilers 15ft. 6in. × 10ft. 6in., 185lb. working pressure.
Engine 24 × 39 × 65 × 45in. stroke, condensing.
Shaft speed 70 r.p.m.
Diameter of propeller 17ft.
Present cost of complete vessel, £33,000.
Present cost of complete machinery and boilers, &c., £9500.

It will, therefore, be observed that the power on the propeller, or shaft horse-power, allowing as high an efficiency as 83 per cent. (an extremely high figure for such slow marine engines), the shaft horse-power at top vessel speed is 1038b.h.p.; it is therefore interesting to note the effect of an electrical power transmission installation in this case, and also the effect on the "commercial" side of the question as regards the reduction of operating costs and the possible higher vessel speed for the same power developed.

It will be noted that the weight of the the whole plant must not exceed 300 tons, and that the cost of same must not exceed £9500 sterling.

The particulars of the plant to meet the above requirements would be as follows: One squirrel-cage induction motor, to run at a speed of 70r.p.m., to give off 1038b.h.p., complete with propeller and shaft, weight per b.h.p. 112lb., equals 52 tons.

Turbo-generator, condenser, &c., capable of giving off 840 kilowatts, weight of which would be 93lbs. per kilowatt, equals 39 tons.

Pipework, under which is included all pumps, water, steam and exhaust pipes,

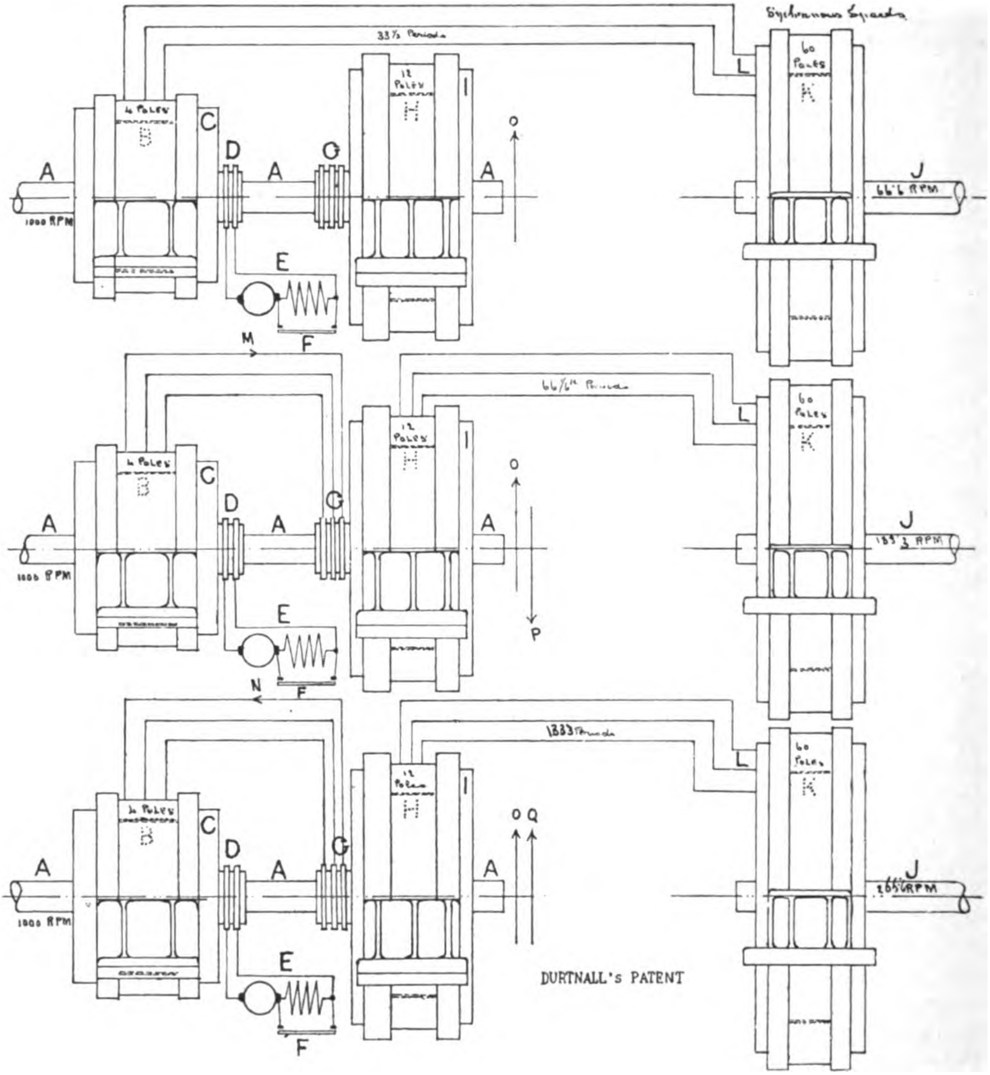

FIG. 25. DESCRIPTION OF THE "PARAGON" SYSTEM OF ELECTRICAL POWER TRANSMISSION AND SPEED REGULATION, INCLUDING REVERSING, ETC., FOR MAIN MARINE PROPULSION.

A. Turbine (or gas engine) shaft revolving constantly in same direction at, say, 1000r.p.m. on which are mounted members B, D, G, and H.
B. Revolving field magnet of alternator (three-phase).
C. Stator or armature of same.
D. Slip-rings (small) which take the exciting continuous current, from exciter E to magnet B.
E. Series wound exciter, for revolving magnet B.
F. Contact which can short-circuit the field of exciter E, therefore making a no-voltage condition throughout the whole system.
G. Slip-rings (small) that take the three-phase current from armature C to primary of transformer-generator H, for the two top speeds of rotor K.
H. Revolving primary of transformer-generator, in use on two top speeds.
I. Stator of transformer-generator, from which three-phase current is taken to motor stator L, on the two top speeds.
J. Propeller shaft that requires to be under variable speed, torque conditions, either ahead or astern.
K. Short-circuited squirrel-cage rotor of induction motor, which is coupled to propeller shaft J.
L. Single-winding stator of induction motor as above, say for 60 poles.
M. Direction of current (three-phase) between armature C and slip-rings G, as arranged for middle speed of rotor K.
N. Direction of above three-phase current at top speed of rotor K.
O. Direction of rotation of prime mover A at all times.
P. Direction of revolving magnetic flux in revolving primary H when supplying current at the middle speed of rotor K.
Q. Direction of revolving magnetic flux in revolving primary H when stator, or secondary I, is supplying current to the motor stator L when rotor K is running at top speed.

gratings, platforms, &c., at 87lb. per shaft h.p.. equals 40 tons.

Boilers, under which are included boilers with small and large mountings, firebox and funnel, at an evaporation of 120lb. of steam per hour per ton weight, equal 119 tons.

Thus the total weight of the power equipment will be 250 tons, or a saving of 50 tons in the machinery alone.

The steam consumption per kilowatt hour will be 17lb., with a steam pressure of 180lb. per square inch, with superheat of 150 degrees, and 28in. vacuum, and running at a speed of 1350r.p.m.; the total steam consumption will therefore be 14,290lb. per hour. Allowing for the auxiliaries a further 6 per cent. gives a total steam consumption of 15,050lb. of steam per hour. Now, allowing an evaporation of 10lb. of water per lb. of coal burnt, the coal consumed per hour will amount to 1505lb., equals 16.13 tons per day, making therefore a saving of about 19 per cent. in coal for the same shaft horsepower.

The total cost of the above plant will not exceed the allowed amount, namely, £9500, including erection on board. The real advantage, however, is that the cost of operation is reduced, in so much that, say the vessel is bound for a very long trip and has a 21-day non-stop run (a thing that is often done), as the coal used per day is only 16.13 tons, the amount of coal to be loaded and carried at the start is only 339 tons, in the place of 420 tons as in the reciprocating-engined ship, and the 50 tons saved in the machinery and the 91 tons saved in the coal consumption makes a saving in dead-weight of no fewer than 141 tons less to be pushed along, effecting its equivalent displacement ; therefore the number of hours taken by the vessel to do the journey will be less, and the total consumption of coal for the trip will be less for that reason ; considerable valuable space can be saved in the vessel, and much more room be given to the disposal of cargo, &c. The case therefore merits the closest investigation, promising as it does a solution to the very vexed question of shipping at the present day.

As the author advocates the use of polyphase alternating-current apparatus and squirrel-cage motors with single windings in connection with this important power transmission and speed regulation scheme for main marine propulsion, it might be very well asked as to how the necessary speed regulation is to be obtained, &c., as to how the large-type induction motor is to be started at work for driving or reversing the propeller, &c.

Fig. 25 shows a method of applying the "Paragon" electrical power transmission system for this purpose of main marine propulsion and especially in large powers and units.

Working conditions.—Say alternator B is 4-pole, and transformer-generator H 12-pole. Assuming that contact F is on and bridging the field of exciter E, start prime-mover A, and, through suitable switch-gear, couple armature C to motor stator L, then by lifting contact F, the voltage will gradually rise in the system, and the rotor K and propeller shaft J will rise to a synchronous speed of 66.6r.p.m. (speed of A, 1000r.p.m.).

Second speed.—Bridge over the contact F, and voltage will immediately fall to zero in the whole system, then change the connections as follows: instead of going to the motor stator L, take the three-phase current from C to slip-rings G, and connect in such a way that current is in the direction marked M ; at the same time connect the motor stator L to the transformer secondary I ; now by lifting contact F, the voltage and periodicity from I to L will rise, and the rotor K will increase to a synchronous speed of 133.3r.p.m.

Top speed.—Bridge over the contact F, when a no-voltage condition will take place in the whole system, then reverse two of the three phases at N, and by lifting contact F the voltage and periodicity will rise, and the rotor K will increase to a synchronous speed of 266.6r.p.m.

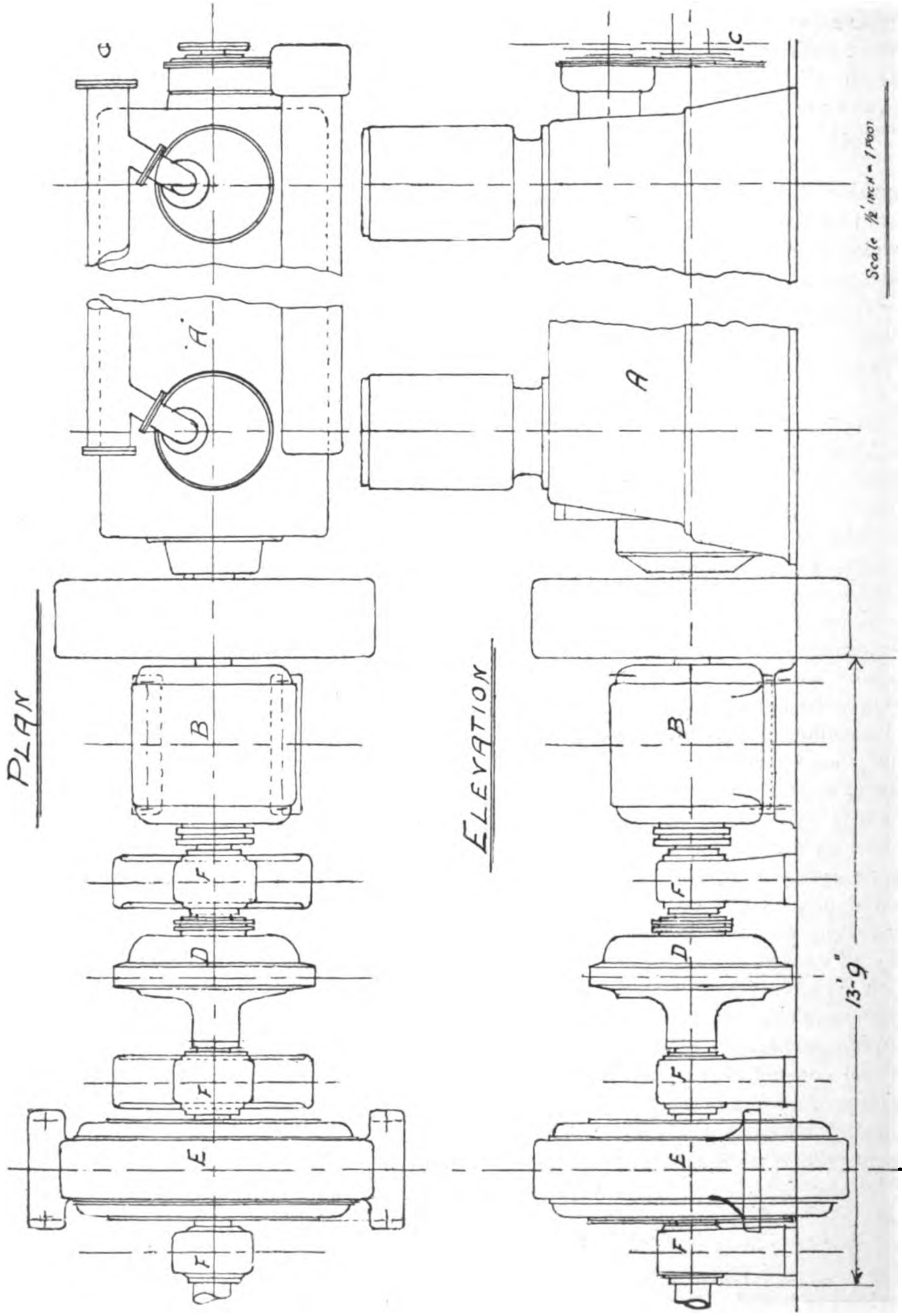

FIG. 26. MECHANICAL ARRANGEMENT OF THE "PARAGON" SYSTEM OF ELECTRIC MARINE PROPULSION; WITH GAS ENGINE AS PRIME MOVER.

Reversing at either of the above speeds.—Bridge over the contact F and voltage will fall into a zero condition, then reverse two of the three phases at L, and the same speeds will be obtained, but in the opposite direction, the prime-mover remaining in the same direction.

Particulars. — When in the first speed condition, the periodicity at L is as follows: Prime-mover speed, 1000, multiplied by 4 generator poles, equals 4000 alternations per minute, therefore 33.3 periods per second.

When on the second speed condition, the periodicity at L is as follows: Prime-mover speed, 1000r.p.m., multiplied by 4 poles, equals 4000 alternations per minute, then prime mover speed, 1000r.p.m, multiplied by 12 transformer-generator poles, equals 12000 alternations, minus 4000 alternations, equals 8000 alternations per minute, therefore 66.65 periods per second.

When in the top speed condition, the periodicity at L is as follows: Prime-mover speed, 1000r.p.m., multiplied by 4 poles, equals 4000 alternations per minute, then prime-mover speed 1000r.p m., multiplied by 12 poles, equals 12000 alternations, added to 4000 alternations equals 16000 alternations per minute, therefore 133.3 periods per second.

It will be observed that if the armature C is mounted on bearings, and a brake attached to same, that by letting the brake slip the armature will endeavour to follow the magnet B, and should the brake be free the armature C will equal the speed of B and the periodicity of the whole system will then be zero, and consequently the rotor K. It will thus be seen that any speed may be obtained on rotor K from zero to 66.6, or to 133.3 or to 266.6, as may be desired, by adjusting the small brake, the turbine running at constant speed. That is the method by which the author proposes to vary the periodicity of the whole system by means of these connections, and "floating fields," in the generator-transformer. This is the right place to do it, because by close investigation it has been found that in dealing with big powers the disposal of the heat given off by large motors is a subject of the importance of which few people are aware. For instance, there would be considerable trouble to get the heat away from a motor fitted with slip-rings; and, in fact, even on motors for 4000 total horse-power with windings in tandem, one behind the other, although acting very well on the small powers, it will be found on investigation that it is not so satisfactory when applied to big powers. Therefore, by using a motor with a single winding on the stator and a squirrel-cage rotor we get the best machine we possibly can have for efficiency; we have a highly efficient motor, therefore a relatively small amount of heat to dispose of; a motor which has a minimum of diameter, so that it may be placed easily in the stern of the vessel; a motor small in cost, which is not an inconsiderable matter in applying the scheme to ship propulsion; and in short a motor that has a maximum of strength and utility as regards electric motors of any description. That is the object of developing the "Paragon" system in this manner, and the author trusts he has made it clear how it is possible to get a variable speed with a squirrel-cage motor having single windings.

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(*To be continued.*)

AUXILIARY ELECTRIC PLANT ON THE CUNARDERS.

In the course of a paper read last month before the Institute of Marine Engineers, Mr. John McLaren introduced a series of very interesting particulars concerning the electrical equipments of the *Lusitania* and *Mauretania*. The use of electric motors on these vessels has been adopted on a greater scale than has ever before been attempted for passenger ship's work. All the motors and lights are operated by continuous current. The *Lusitania* has eleven passenger and baggage lifts as follows: Two passenger lifts, 10cwt. each, operated by 8h.p. motors; two baggage lifts, 40cwt. capacity, operated by 15h.p. motors; two service lifts, 10cwt. each, operated by 5h.p. motors; three food lifts, of 2cwt. each, operated by 1½h.p. motors; and two ash hoists, of 2cwt. each, operated by 3¼h.p. motors.

The electric lighting sets consist of four generators direct coupled to Parson's turbines, running at 1200r.p.m. The output of each set is 375kw., or 500h.p., at 110 to 120 volts, shunt wound. In the galley electricity is largely used for driving the patent roasters, and bread-making machinery, meat-slicing, potato-peeling, sandwich-making, dish-washing, cream-freezing and whisking machines are all operated by electricity.

The refrigerating machinery, in duplicate, is operated by an electric motor, with a variable speed regulation from 40 to 110 r.p.m. The centrifugal pump for circulating the brine is driven by a small motor. The thermo tanks are also electrically operated.

The forced-draught fans for the boilers, sixteen in all, are driven by 50h.p. motors, 100 volts at 450revs. maximum to 185 minimum. These motors have been provided with special means of ventilation owing to the high temperature in which they have to work. The engine room is ventilated by twelve fans driven by motors. On test the temperature rise of these and the stokehold fans was under 50deg. F.

For boat lifting four hoists are provided capable of lifting 12cwt. at 250ft. per minute. Each hoist is operated by a 14b.h.p. motor, 110 volts at 600r.p.m. For deck purposes four cranes are provided of 30cwt. capacity each, separate motors being used for lifting and slewing. For lifting, a 15h.p. 500revs. motor is installed, with worm reduction gear. The slewing motor is 2½b.h.p. at 750r.p.m. The steam-driven auxiliaries are the circulating pumps for the main condensers, which are driven by a 358b.h.p. engine running at 300r.p.m. There are three steam winches for cargo holds, two of which are 8in. by 14in. and one 12in. by 16in. There are eight steam-driven capstans, four forward and four aft, each of which is driven by a 1000h.p. engine. All of these steam-driven auxiliaries could very easily have been driven by electric motors.

The details of the *Mauretania* are somewhat similar as far as the auxiliaries are concerned. The galley is fitted with electric egg-boilers, grillers, hot plates and knife cleaners.

The engine-room ventilating fans consist of ten 4h.p. fans, eight 5h.p. fans, six 2.5h.p. fans, and four 1h.p. fans, all specially ventilated as in her sister ship, the stokehold fans being the same as in the *Lusitania* The 75in. and 60in. sluice valves are each operated by two 12h.p. motors. A rather novel feature in these two boats is the electrically-operated whistles.

The above particulars will show to what extent the advantages of electricity for operating this class of machinery have been recognised by the designers of to-day.

WIRELESS TELEGRAPHY ON BOARD SHIP.

EVEN in these days of new discoveries the invention and application of wireless telegraphy stands in the front rank as one of the greatest achievements of modern science. Improvements have followed one another in rapid succession, and indeed wireless electrical transmission has become the fashionable theme of the inventor and scientist. The great progress of Hertzian wave telegraphy has been due almost entirely to the immense service it has rendered to shipping generally; the merchant is no longer cut off from the outside world during voyages from continent to continent; not only is he in constant communication with his business on shore, but he is able to enjoy the luxury of his daily newspaper.

The value of radio-telegraphy to the shipowner cannot be over-estimated; the position of a ship fitted with the modern telegraph can be accurately followed and her time of arrival fixed with far more certainty than before its adoption. Passengers now travel with a greater sense of security, knowing that if accident should happen the flashing of the distress signal, viz., "SOS," would bring ships from all points of the compass rushing to the aid of the disabled boat. The recent event where the lives of the passengers and crew of the ss. *Republic* were saved by wireless telegraphy from almost certain death, is still fresh in the minds of everyone; this is, however, but one of the many incidents in which help has been obtained through this medium, and it is safe to say that ere long the fog at sea, which is so disastrous to shipping, will lose many of its terrors when mariners by the aid of wireless will be able to locate the exact position of their own and that of other vessels in the immediate vicinity. The time may also not be far distant when the inefficient methods of signalling by means of flags will be superseded by the more practical and infinitely superior method of wireless telegraphy.

With quite a small installation a range of fifty miles is easily obtained. At the present time there are several more or less known systems suitable for ships, which have been thoroughly tested and proved reliable.

It may be of interest before going further to recount a few of the early experiments which were carried out by Mr. Marconi and others. Prior to the year 1896, when Mr. Marconi first brought his historical "secret box" to this country, Sir William Preece, F.R.S., had been engaged in some very interesting and successful experiments in wireless telegraphy between Rathlin Island and the mainland. The distance covered was approximately two and a half miles, and for a considerable time the apparatus was used by the military authorities.

The system had, however, serious limitations, which can easily be comprehended when it is understood that in order to signal over a given distance it was found necessary to stretch two telegraph lines parallel and opposite one another, each wire being equal in length to the distance between the stations. On the advent of Mr. Marconi in England further experiments in the above system practically ceased. Sir William Preece quickly perceived the enormous advantages of the former's apparatus and its *modus operandi*, and at once interested himself in its further development.

In the light of present-day knowledge one is apt to forget the work of the pioneers, but it is a generally recognised fact that but for the kindly assistance of Preece, not only personally but also officially, Marconi's system would not have held the position it does to-day, either technically or commercially.

The most important of Marconi's early experiments were those carried out between Bournemouth and the Needles, a distance of ten miles. These took place in the year 1898, and it is interesting to note that in these tests the signalling speed was something between three and four words per minute. Subsequently these stations were removed to Poole and St. Catherine's Point respectively.

In 1899 Marconi established wireless communication across the Channel, between the South Foreland Lighthouse and Wimereux, near Boulogne, and at this time public excitement about the new method of telegraphy was at its zenith.

On Dec. 12, 1901, Marconi received signals across the Atlantic at St. John's, Newfoundland, from a large station at Poldhu, in Cornwall. This station was principally designed, so far as the plant was concerned, by Dr. J. A. Fleming, M.A., F.R.S., whose contributions to electrical science are well known.

It would not be fair in passing to omit mention of the experiments carried out in 1903 by Dr. Lee de Forest between Holyhead and Howth Point, in Ireland. Although the distance covered was comparatively short, considerable significance can be attached to these tests, since they demonstrated a very important fact, viz.—the possibility of two wireless stations of approximately equal power operating simultaneously without in any degree interfering with one another, since within two or three miles of the Holyhead station a Marconi installation was also exchanging messages with Atlantic liners carrying wireless installations.

Mention should also be made of more recent work, but as space is limited, the writer will content himself by giving results obtained during 1908 by the Amalgamated Radio Telegraph Company at their radio station at Cullercoats, near Newcastle.

By means of their latest and most perfected type of recorder signals have been received at the above station from Lyngby, in Denmark, and printed at the rate of 100 words per minute.

In referring to the early work, the object has been to show how this system of communication has been improved from a technical point of view, and it is now to be shown what enormous advantages are to be gained from equipping vessels with this means of signalling.

Unfortunately, through the desire of interested parties to advertize particular systems of radio-telegraphy, the public have from time to time been apprised, through the medium of the daily press, of extraordinary feats, or better freaks, of communications which may have occurred from time to time but cannot be repeated, and is thus led into believing that vast improvements and developments are going to be made—beliefs which unfortunately have rarely, if ever, been realised by actual results.

This method of disguised advertisement has done much harm to this particular branch of science, since the investing public quickly tire—and rightly so—of hearing promises which have so persistently been unfulfilled, and the capitalist at the present time consequently regards with great scepticism any new and genuine system or improvement which may be brought out by some workers or inventors of unknown *public* repute, but who nevertheless possess great scientific attainments.

Nothing succeeds like success is the old adage; but how is success to be attained unless facilities are granted by those who can afford them? A very practical instance of the very apathetic attitude of certain classes of English shipowners is afforded by the following: About three years ago it was the writer's privilege to present a scheme to two or three companies owning large fleets of fishing vessels, for equipping some of their vessels with installations of wireless telegraphy apparatus. Among one of the advantages placed before them was the not inconsiderable one of adjusting the arrival of the fleet in port when the market prices were high. To be brief, nothing came of the scheme, but it is interesting to note that our neighbours the Germans have recently adopted practically the same idea, and a number of their North Sea fishing vessels are fitted with installations which appear to give every satisfaction, and answer the purpose for which they were required.

In order to give the reader better information regarding the actual possibilities of radio-telegraphy, a few facts concerning the apparatus employed and its capabilities may be of interest.

To commence with, the distance over which signals can be transmitted and received depends on several factors. The most important of these is the power used in the transmitter. The greater the power, the greater the distance. The distance, however, does not increase in direct ratio to the power employed.

Modern vessels of even quite small tonnage have electric light installations on board, and where this is the case, the telegraphic power may be obtained directly from this source. The normal power allowed for vessels under the regulations laid down in the International Convention of Radio-telegraphy, is one kilowatt or roughly 1⅓h.p. This power is sufficient to cover under all circumstances, with one exception, a distance of 200 miles. At times, this distance would be far exceeded, but we are not dealing with possibilities but actual facts. For distances less than the above, say 100 miles, ½h.p. is ample, and normally considerably less than this can be employed. These figures are, of course, applicable only to communications over sea and not over land.

Other factors which determine the signalling distance are—atmospheric conditions, daylight effects, and the receiving appliances employed. Regarding atmospheric conditions the distance is immensely increased when a fog or sea mist is present—a fact, it should be noted, of a most advantageous character. Wind and rain make little or no difference to the transmission, although the latter may sometimes reduce the range owing to want of care on the part of the operator using the apparatus in the supervision of the plant and maintaining the proper degree of insulation of the radiating wire, or antenna, as it is technically named. The influence of strong sunlight is to reduce the signalling distance, but this is to some extent nullified by the increase due to darkness. The reader should bear in mind, however, that the above figures represent the minimum distances under all these conditions.

Coming now to the apparatus itself, this can be divided into two classes—that used for transmitting and that for receiving.

In the present state of the art it is not possible to send and receive messages at the same moment.

When the transmitter is in operation the receiver is temporarily disconnected and *vice versa.*

Transmitters again can be divided into two classes—those which can inter-communicate with all receiving apparatus adjusted to respond easily to them, and those which only affect instruments very delicately adjusted to them.

The former are termed *spark* transmitters and the latter *arc* transmitters.

For shipwork, the *spark* apparatus is undoubtedly the superior, both from a technical and practical standpoint, since it is obvious that inter-communication with all other stations is not only desirable but absolutely essential if the safety of the vessel is to be assured.

Hence, since the object of this article is to deal with radio-telegraphy on ships principally, only the spark form of transmitter will be discussed.

This part of the installation is the most complicated; that is, if any of it can be called complicated as compared with the other machinery now in use on modern ships. For small plants a battery of accumulators, consisting of eight to ten cells, charged from the electric light installation, and connected to the sparking instrument, technically called an induction coil, cannot be much improved upon. By the use of accumulators, placed in a part of the ship which would be least likely to sustain damage either by collision or storm, there is always a store of energy available for signalling in the event of the machinery in the engine-room being disabled. The provision of such auxiliary source of energy should be insisted upon by owners contemplating the equipment of their vessels.

For larger powers, from ½h.p. and upwards, a small rotary-converter is employed.

This machine is used in conjunction with a slightly different form of sparking instrument; in fact, the converter generates alternating current and supplies an ordinary high-tension step-up static transformer. This converter may be housed in any convenient corner, either on deck or just below, and is normally driven by current from the lighting installation, or in the case of failure due to accident, by current from accumulators, or in other cases, and if preferred, by a small petrol or oil engine.

There is another method of obtaining high-tension electric energy, which, although up to the present not in practical use, would appear to have advantages over existing methods so far as first cost and simplicity are concerned. It consists of forcing steam at a pressure of from 75lb. to 100lb. per square inch through specially constructed nozzles, the vapour subsequently passing through a well-insulated metal tank or box, in which a few metal points are inserted.

Owing to the friction of the particles of water through the nozzles, electricity is generated in considerable quantities and the tank or box becomes powerfully charged. This apparatus has been much improved recently, and the writer has witnessed pressures of 60,000 volts to 100,000 volts so generated and registered by a Kelvin electrostatic voltmeter.

By the use of this apparatus all converters, transformers, &c., can be dispensed with and the energy taken direct to the aerial conductor or other capacity. There is also a further advantage with this form of generator, in that there is absolutely nothing to get out of order and any marine engineer can effect the occasional renewal of the special friction pieces of the nozzles.

To return to the transmitters employed at the present time, the energy from the induction coil or high-tension transformer is led into a condenser. This condenser generally takes the form of a number of Leyden jars arranged in series or parallel according to the different systems. The use of this form of condenser is to be deprecated for two reasons. The first is the rapid deterioration of the metal surfaces owing to the formation of nitric acid when they are in use; and the second is the large amount of space which is occupied. Very compact serviceable oil condensers can be now obtained, and give little or no trouble.

It is the discharge of the condenser which gives rise to the Hertzian waves which are radiated into space from the aerial or antenna. The latter consists of from one to four or more conductors suspended from or between the masts of the vessel; these aerial conductors should be preferably of phosphor-bronze wires on account of its strength and durability.

In order to set up the waves or oscillations which radiate from the antenna, and which, as said, are generated by the condenser discharge, either one or the other of two types of instruments are generally employed. One is called an oscillation transformer and the other a Helix.

The Helix instrument is the more efficient, but the former offers certain advantages, especially when the primary power exceeds half a kilowatt. The Helix has the advantage of simplicity and immunity from breakdown, whilst the transformer is more costly to manufacture, more complicated, and is more liable to cause trouble through breakdown, although it should be mentioned that this latter is an extremely rare occurrence.

A spark gap, preferably enclosed by some

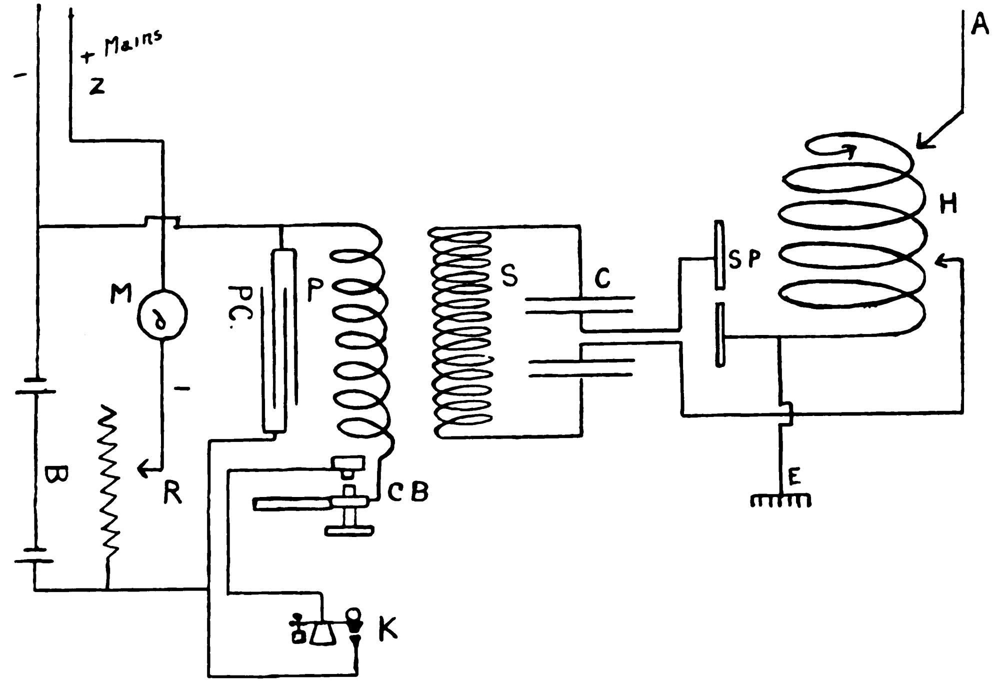


Fig. 1.

well-insulating and non-hydroscopic material, is also an essential.

The two diagrams, Figs. 1 and 2, show the complete transmitter connections of two plants, using apparatus as described.

Diagram Fig. 1 shows the arrangement of apparatus suitable for working up to a minimum distance of 100 miles, whilst Fig. 2 represents a more powerful installation for working up to 200 miles.

It may be of interest to give here a brief explanation of the generation of the oscillations which can operate suitable receivers over such great distances. If the reader will consider the case of a simple pendulum capable of swinging to and fro, or, in other words, performing a series of oscillations, and will assume this pendulum to be held some distance from its vertical axis, and then suddenly released, it will be noticed (*a*) the pendulum oscillates and finally comes to rest, (*b*) it oscillates at a certain definite rate, (*c*) that the rate or frequency of oscillation is not affected by the amplitude of each swing. As is well known, the rate of oscillation is determined by the weight of the bob and the length of the pendulum or the distance from the pivot or point of suspension to the centre of the weight.

To consider the electrical equivalent. The condenser corresponds to the weight, and the length of the wire between it and the spark gap to the distance. Owing to this gap, the induction coil or transformer is enabled to charge the condenser up to a certain point—determined by the distance separating the two electrodes—when suddenly the strain becomes too great, and a spark is produced. Now, it is at this point that the oscillations are created, since the condenser in discharging does so in the same manner as the pendulum, viz., in an oscillatory manner.

On all vessels other than those of the Navy, the size of the condenser and the length of wire in its circuit must be such that oscillations occur at a frequency of 1,000,000 per second, at which frequency the antenna will radiate a wave of approximately 1000ft. or 300 metres length. This is a standard

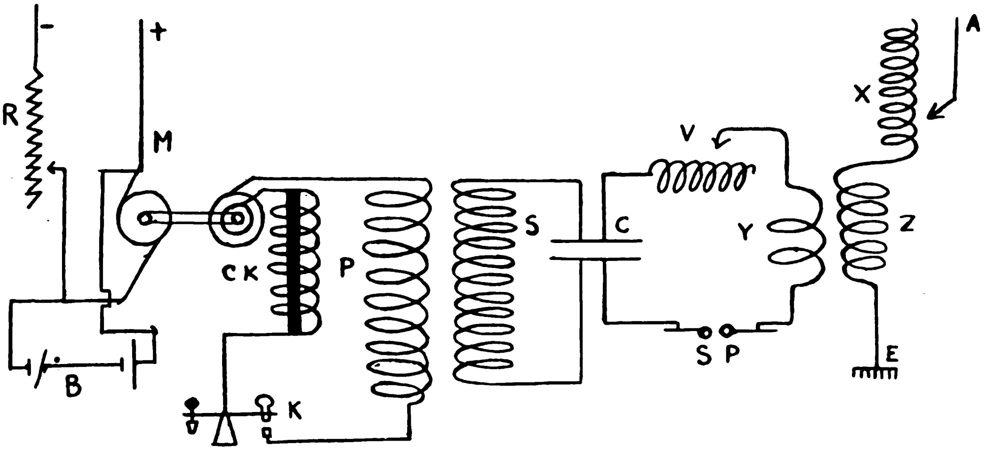


FIG. 2.

wave length for vessels, and they must be able to produce it. They *may* in addition be able to obtain any other wave length not exceeding 2000ft. or 600 metres, but the 300-metre standard must be adhered to, except in the cases of small vessels, when special waves may be allowed.

The object of thus standardising wave-lengths is primarily to enable all vessels of any nationality and carrying such receiving apparatus capable of being operated by "spark" transmitters to readily inter-communicate.

With regard to the receiving apparatus, there is little to be said. For practical radio-telegraphy, only those types of receivers which employ telephones worn by the operator are of any value. Of these there are several types available, but only two stand out well to the front of others. They are known as the electrolytic and the magnetic types respectively.

The former is by far the more sensitive, and is very reliable in the hands of a careful operator; but the latter is absolutely "fool proof." A good up-to-date installation should include both types of these receivers.

There are several recording receivers also on the market, but, although possessing certain advantages over the telephonic type, they are generally unreliable in their action, more or less complicated to adjust, and expensive; moreover, the speed of signalling with them averages only about 12 words per minute, whereas with the telephonic type speeds of 25 to 30 per minute or even more can be obtained; in fact, with telephonic receivers the speed is limited only according to the ability of the operators.

Radio-telegraphy plays a most important part in the working of His Majesty's Navy. Practically all men-of-war are fitted with apparatus designed in part by Mr. Marconi and by Capt. Jackson, R.N., the latter being one of the early experimenters. Constant communication is maintained throughout the different fleets, orders are given, and manœuvres executed from instructions radiated from the flagship.

The Admiralty building at Whitehall is equipped with a long-distance installation, and from its antenna messages from ships at sea are both sent and received. By this means the progress of manœuvres and latest information is obtained by headquarters. Some of the largest and more recent types of vessels have very powerful installations with a range of several hundred miles.

It is sometimes argued that the comparatively simple manner in which messages can be tapped would be disastrous during time of war, as the enemy would be able to receive signals intended for our own ships. This disadvantage is easily nullified when secret codes are used, and as a matter of fact it would be possible to cause considerable confusion amongst the opposing fleet if information likely to lead them astray were transmitted.

Dealing now with the commercial side, most of the large liners have installations and are open for public correspondence, and telegrams can be despatched to and from the coast or other vessels.

When a ship station has traffic for shore the operator waits until the coast station required is nearest to the ship; he then signals the call of that place. On the reply being received the boat indicates the number of miles she is from the coast station, her bearing, course, speed, and the number of words to be transmitted; this information is supplied so as to enable the shore, in cases where two or more vessels require to communicate at the same time, to give preference to the boat whose position, &c., shows that she will be the first to pass out of range. After a telegram has been received by the coast station it is then retransmitted over the landlines to the office of destination.

The rules for acceptance of radio telegrams are somewhat similar to those adopted by the British Post Office. The cost of the message is made up of the ship station charge, the coast station charge, and the fee for transmission over the landlines. Money-order or reply-paid telegrams are not allowed.

Press messages containing the latest information from the outside world are sent daily from certain shore stations and are read by ships within range, which in their turn retransmit to other vessels in reach of their apparatus; the news received is then printed in the form of a newspaper and sold on board.

The operator requires to be a man with considerable technical knowledge as well as a skilled telegraphist; he cannot take charge of a ship station unless he holds the Postmaster-General's Certificate, which is granted when an examination in sending, receiving, and practical wireless telegraphy has been passed.

The rules for working were framed at the Berlin Conference of the International Radio Telegraph Convention, for the purpose of arranging regulations, &c., whereby it is possible for ships of all nations to intercommunicate.

Before a ship registered in the United Kingdom can be installed with apparatus a licence must first be obtained from the Postmaster-General, and certain restrictions, are laid down as to power, wave length, &c. These stations must be opened from time to time to inspection by Government officials. Vessels fitted are compelled to interchange telegrams with all coast stations, but are not bound to communicate with other ships except in cases of distress, when such distress signals take priority over all others. Next in importance to these come Admiralty messages. Coast and ship stations are required to suspend all other communication when requested to do so by the naval authorities.

An official list giving all information as to call signal, wave lengths, system used, normal range, hours of service, &c., is published by the International Telegraph Bureau at Berne, and all stations are required to possess a copy.

The Postmaster-General has power to cancel the licence of any British ship failing to comply with the regulations laid down, or in the case of a foreign ship to authorise coast stations in the United Kingdom to refuse communication.

Some description of the action and construction of both the electrolytic and magnetic receivers may be of interest. The construction of the former is as follows: A fine glass tube about 2cm. in length and 1mm. bore has one of its ends drawn out to a point. Sealed in this point, and securely fastened to a thicker wire inside the tube is a fine platinum wire .02mm. diameter. The outside projecting portion of this wire after the glass has been sealed upon it is subsequently broken off, leaving only the cross-section exposed. The thicker wire inside the tube is attached to a stout silver plug, which slides easily through a brass collar which in turn forms a convenient support for holding the point in position.

Other parts of the instrument include a delicate potentiometer, three small dry batteries, a pair of delicate telephones, and a small cup containing a solution of caustic potash or dilute sulphuric acid.

The sensitiveness of the receiver depends to a very great extent on the telephone resistance, which should be as high as possible, generally of the order of 5000 to 6000 ohms the pair.

The point dips into the solution contained in the cup, and is polarised by the dry battery, a film of oxygen gas being produced on the fine platinum wire exposed.

On the arrival of the oscillation energy produced by a spark transmitter, the film of gas is heated and the resistance is reduced; more current therefore can flow through the telephone, and a click or buzz is produced. The connections of this receiver are shown in Fig. 3.

The usual form of magnetic detector consists of an endless rope of silk-covered iron wire which passes round two pulleys about four inches in diameter, and kept in continuous motion by clockwork. This rope passes through a small glass tube upon which are wound a few turns in one layer of fine silk-covered copper wire. Over this and on a small bobbin is a second winding of much finer wire, this being connected to the telephones.

Two horse-shoe magnets with their like poles adjacent and opposite the secondary bobbin complete the instrument. The action is very simple, being due to the fact that high-frequency oscillations tend to reduce the "hysteresis" of iron, consequently since the magnetic field is normally constant about the secondary winding, any oscillations in the primary cause a change in this state and secondary momentary currents are induced which in turn actuate the telephones.

There is another very practical type of magnetic detector, which has been recently devised and promises to far exceed in sensitiveness the moving rope kind, but as it is not yet commercially launched, the writer prefers to reserve further details for the moment. It can be mentioned, however, that the instrument has proved itself very applicable to wireless telephony.

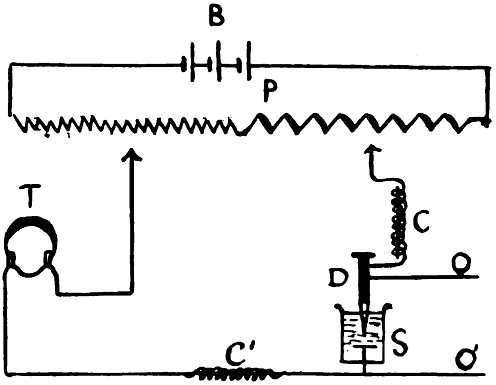


FIG. 3.

In practice it is found necessary that all vessels should be provided with a suitable receiving tuning device. Just as it is possible to adjust the transmitter to radiate a wave of predetermined length, so is it possible to make the receiver respond to any given wave, and that wave only, within certain limits.

Of tuning devices there are a great number. They consist essentially of adjustable inductances and condensers, arranged in various ways

Perhaps the best at the present time is the latest Marconi device, which is the outcome of many years' study and experience. Fig. 4 shows a magnetic detector coupled to such a tuner, and it may be mentioned that very accurate results can be obtained with it. The advantage of having such a device is obvious, since once communication is established with a station, a rapid adjustment of the tuner brings the signals in much louder; at the same time any other stations in close proximity, working on a wave length differing only by perhaps 100ft. or 200ft. from the transmitting station's wave, can be readily cut out.

Of other similar apparatus, mention can be made of the De Forest three-coil tuner and the variometer. This latter device is really one of the best types, since all sliding contacts are dispensed with. A simple

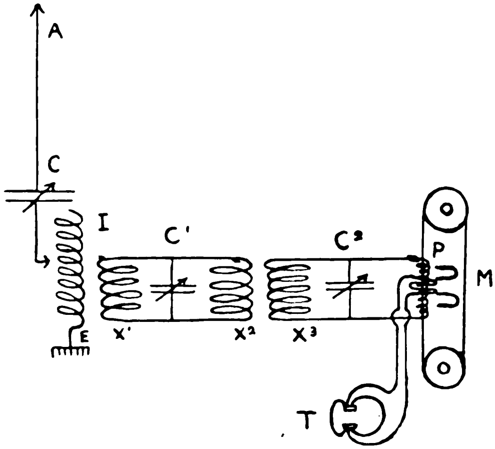


Fig. 4.

movement of two superimposed windings in respect to their inductive relation to each other is all that is required to attune the receiver to the transmitter. The correct position is found to the minutest fraction of a degree in a few seconds. Furthermore, cheapness is another important factor in its favour.

There is one other piece of apparatus which it has been made compulsory to have on board, and that is a wave-meter or measurer. These instruments are of various types, but can be made up in a very portable form. As their name suggests, they are used to measure accurately the wave length transmitted and at times received.

Having thus mentioned and described all the principal apparatus necessary for a complete installation for a vessel, it now remains to summarise a few general points both as regards telegraphic working, initial and maintenance costs, &c.

It was stated in an earlier part of this article that certain distances could be covered subject to one exception. That exception is when communication is desired during severe atmospheric disturbances, such as thunderstorms. Just as these storms play havoc with ordinary telegraph and telephone lines, rendering not only the circuits unworkable, but at times dangerous to the operators, so do such storms render radio-telegraphic apparatus useless for the time being. It should, however, be noted that the antenna forms a very efficient protection to other parts of the vessel when lightning is present, provided it is well earthed on the ship's hull, and since it is always arranged so as to be out of reach of passengers, no personal harm from this source has ever been known to occur.

A question the writer has had asked him several times is, "Does the apparatus affect the compasses at all?" The reply is in the negative, provided the transmitting apparatus is placed about 10ft. or 20ft. from the instruments in question.

It is hardly within the scope of this article to deal with such questions as those of costs, since so many factors have to be taken into consideration, but a few approximate figures may be useful as a guide to those unacquainted with this class of apparatus.

A complete installation capable of working over a distance of one hundred miles or more should not exceed £70 to £80, and for a greater distance, say up to 200 miles, from £120 to £130. In addition to this there is the cost of installation, depending on the part of the world in which the vessel is situated. The depreciation on the plant is quite small, the chief item being the outside gear, including the antenna, insulators, ropes, &c., which must be renewed from time to time, say once a year. Five to six pounds should cover everything for the short-distance plant, and from £10-£15 on the other. Next comes the vexed question of the operator. That the apparatus requires to be handled with care and intelligence is undeniable; furthermore the operator must be able to send and receive messages by the Morse code at an average speed of twenty words per minute; but these facts do not necessitate the employment of a special man solely for the purpose of telegraphing. It is quite possible for a member of a crew to be trained in two or three months and obtain the Government certificate, and the signalling could be made one of his duties at a comparatively slight increase of salary.

Before concluding this article a few words on the advent of commercial wireless telephony may be given. That this form of communication will eventually solve the qualified operator difficulty is unquestionable, but up to the present no great advancements have been made from a practical point of view. Experienced engineers have been able to hold telephonic communication over distances varying from 50 miles to 300 miles, but unreliability renders the commercial adoption of the system impossible.

That radio-telephony will shortly be within practical politics the writer is confident, since the production of the necessary oscillation energy is being accomplished by means of special dynamos or alternators, which are capable of giving frequencies of 240,000 per second. It is only owing to small mechanical difficulties which present themselves that these generators are not yet on the market, but that these difficulties will be overcome in the near future is unquestionable. Radio-telephony will then be as simple as ordinary telephony is at the present time.

In conclusion, it is hoped that considerable encouragement will be extended by ship-owners to this branch of electrical science which can serve them so well and which has already shown itself worthy to be classed among the great discoveries of the nineteenth century.

MAURICE CHILDS.

MODERN PLANT AS APPLIED TO SHIPBUILDING.

THE title may possibly suggest to some that this article will cover every description of power plant that may be used in shipbuilding works, but this is not the case, as the writer will only deal with electricity as being essentially the modern motive power, and the application of the electric motor to the various machine tools commonly used in shipyard practice. Recent years have seen great improvements effected in electrical plant, in the direction which makes for reliability and money-saving in the heavier industrial works, and in particular the perfecting of the alternating-current motor has solved many difficulties encountered in the earlier days of electrical power-driven works. When the alternating current was first introduced it was on the single-phase system, and did not prove successful for power purposes. Even when three-phase currents were available there were many prejudices to overcome before the alternating current on any system found any great following among shipbuilders. Now that it has been proved to be an efficient and economical method, a great number of works have introduced that type of electrical plant for their motive power and found it to be all that could be desired.

Electrical power systems by direct current and by three-phase alternating current have each their respective merits, and which is the better method can only be ascertained for each case after carefully considering the local conditions.

By using the direct-current method a greater speed variation on the motors can be obtained, but with the alternating-current motor any commutation troubles are eliminated. In ship-building and engineering works there are few machine tools which require speed variation, and as alternating-current motors are cheaper and their construction is of the simplest, the writer would advise the use of same in practically all such works. There are two chief types of alternating-current motors—the short-circuited rotor or "squirrel-cage" type, and the slip-ring type. Polyphase motors require no commutators, and if no starting resistance be used with the rotor circuit no slip-rings are required.

"Squirrel-cage" motors have sufficient starting torque to enable them to start up under fairly heavy loads and have a very high efficiency. For speed variation and for starting with great torque, the slip-ring type is used. Adjustable resistances are inserted in the rotor circuit by means of the slip-rings; in this way the motor speed may be regulated between wide limits when running, and starting up on heavy load is ensured. The speed of polyphase motors decreases as the load increases and acts somewhat similarly to the slip of a belt on a pulley.

With these short remarks on the alternating-current polyphase motors, we will now deal with the economical points which prompt the adoption of such a plant for shipbuilding works as compared with the old style of steam engine power. In an electrically equipped works there are none of the long lengths of steam piping connecting the main engines and the various auxiliaries, as in the old-fashioned way, and here we see at a glance that there is room for a large saving in fuel consumption owing to the elimination of the great condensation that takes place in the piping, the loss of steam through leaky joints, and also the risk of breakdown due to

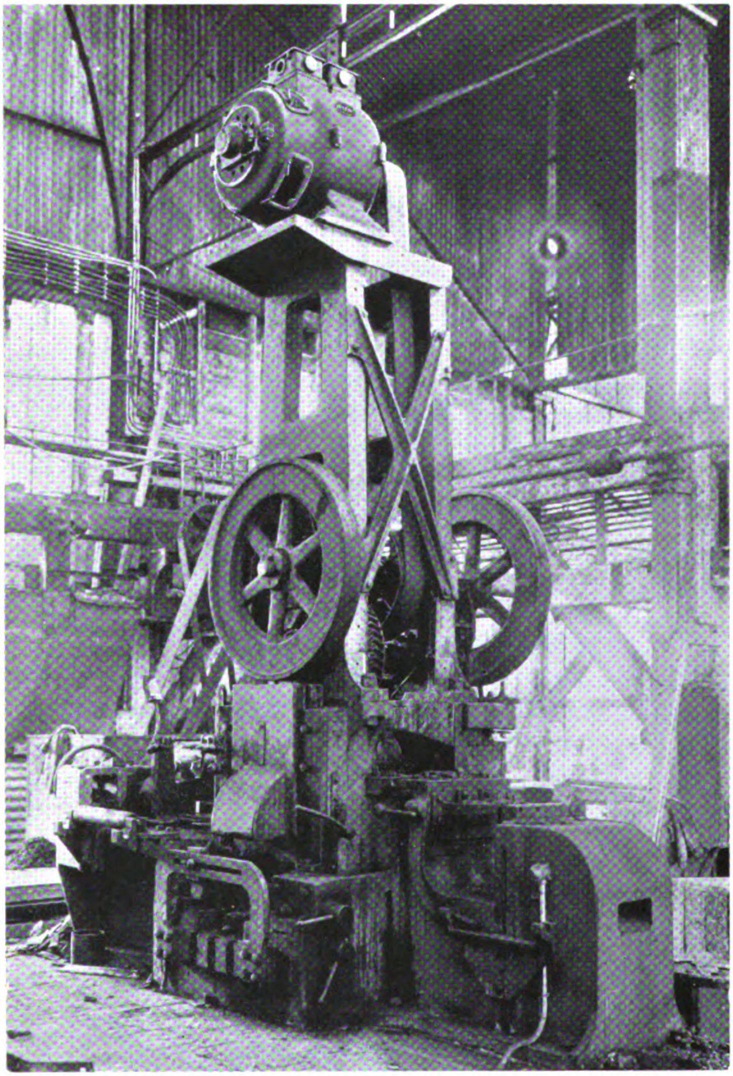


Fig. 1. The Adaptation of a Steam-driven Punch for Belt-drive by Electric Motor.

water lying in the pipes, &c. By using electric power we have the disappearance of "no-load losses," for in a steam-driven works a full pressure of steam has always to be kept at the stop valves of the various engines even although no work is being done, whilst with electric motor driving neither the motors nor the transmission wires consume any current when the motor is at rest.

Another point which is of very considerable importance, and often overlooked in the calculation of economy, is the power taken to drive the long lengths of main shafting. This very often approaches the large figure of 70 per cent. of the total engine power, and never less than 10 per cent. unless in very small plants. By substituting electric motors, either driving short lengths of shafting which in turn drive the counter-shafting of various machine tools in a group, or motors which are geared direct to the machine tools, there is a great saving effected in the power consumed; in fact, the total horse-power required to drive works electrically in this way would be reduced in proportion to the length of main shafting displaced.

Still another point: if any particular machine has to be worked in overtime, with the main shaft drive often the whole length of shafting has to be run, while with the electrical drive only the group the particular machine tool is in is started up, or if it is an individually driven tool that machine only is run, thus saving not only power but the ordinary wear-and-tear of the shafting and belts.

The two factors in machine driving by electric motors which decide the type of motors to be used are torque and speed, and these resolve themselves into the following combinations:—

Constant torque and constant speed, which are met with in pumps, &c. Constant torque and variable speed, in the case of hoisting machines. Variable torque and constant speed in most of the other machines and tools. Variable torque and variable speed in traction machinery. In the transmission of electric power there are the two distinct methods of driving, as already mentioned, viz., (1) Group driving and (2) Individually driven machines. In group driving the machine tools to be driven are divided into convenient groups, each group being driven as a unit by an electric motor driving a short length of shafting from which the several machines are driven by belting. As a general rule it is better to group small machine tools into units and to drive each of the larger tools sepaiately with an independent motor. In separate driving each machine tool is driven by its own motor, and if it were not that the first cost would be large, it would be the most efficient system of power transmission to drive every machine tool in this way.

Punches and Shears.

In the electric driving of machine tools, such as punching and shearing machines, there have been difficulties to overcome mainly owing to the nature of their load and the necessity for having clear working space all round the machine. The effects of the sudden shocks of the load have been very nearly eliminated by the use of heavy flywheels which are capable of storing the energy to overcome the widely varying load demands; also, if the machine is driven through belting, the motor being placed on top of the machine, the slip of the belt when the load comes on always helps the motor. These machines can be driven in the group system or by separate motors, and are either driven through belting or gearing. Fig. 1 gives an

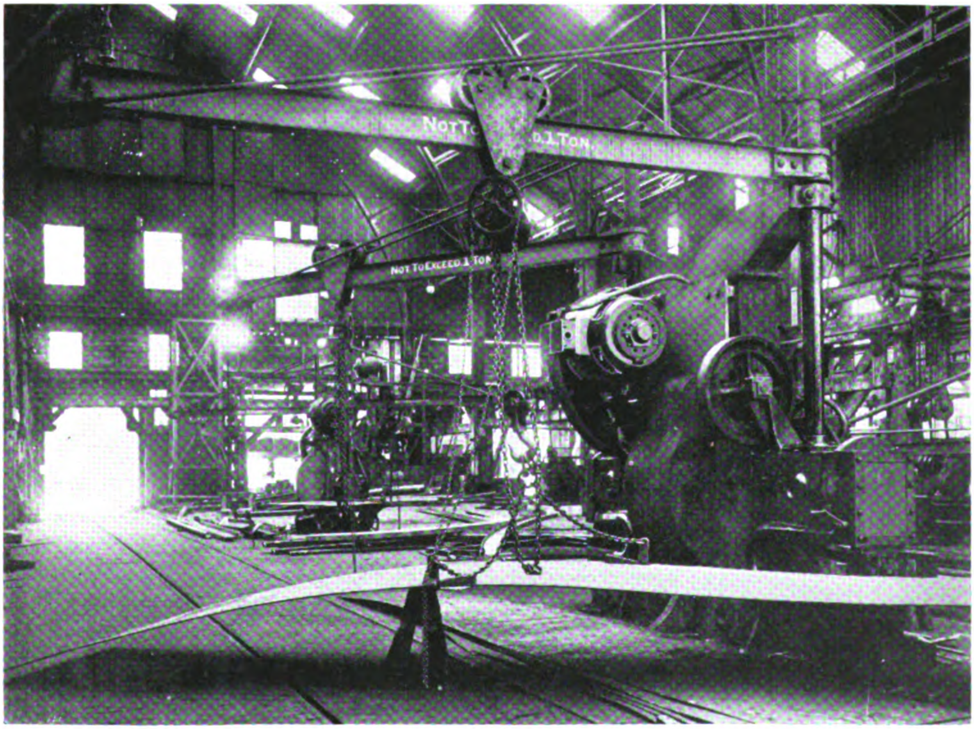


FIG. 2. ELECTRIC PUNCHING MACHINE WITH SPUR-GEAR DRIVE.

excellent illustration of a belt-driven punching and shearing machine, which was altered for the electric drive from its original steam drive. A structure of girders has been built on to the frame of the machine to carry the sole plate for the motor. Fig. 2 gives another illustration of a similar machine with the motor fitted to a plate which is fixed to the side of the frame of the tool. The motor in this case drives through spur gearing, having a speed ratio of 6 to 1. This gives an excellent drive, and with three-phase alternating current one need never have fear of a breakdown, for, as already explained, the motor has in itself the property of "electric slip" and yields when an extra heavy load comes on to the machine.

When two or three punching and shearing machines are grouped together in a shed they can be driven by the group system, a small length of shafting driving the required number of tools. They do not need any counter shafting, being driven direct from the common main shaft. This does not give such an economical drive as the direct-driven tool, but it is a consideration when taking capital outlay into account, and where one is adapting an old yard for the electric drive.

There have been many differences of opinion over the horse-power required to drive such machines as punching and shearing tools, some people installing as high a power as a 20h.p. motor and even above that for driving machines suitable for punching holes of 1in. diameter in 1¼in. plates; but it is not, in the writer's opinion, economical nor necessary to instal so high a power. These machines come under the conditions of the variable torque and constant speed, and as all motors as rated by the leading makers are equal to taking an overload of at least 25 per cent. for one hour, it is as well to take advantage of the fact and use as the most economical size a motor of about 12h.p. The punch and also the shear only demand a momentary full load of the motor, and even then the motor is helped greatly by the flywheel effect.

Countersinking Machines.

Coming to countersinking machines, Fig. 3 gives an excellent illustration of the adaptability of the electric motor to machine tools. Here we have the motor fitted to the jib or arm of the countersinking machine and driving the tool through spur-gearing. The motor, as will be seen, is in such a position that it does not interfere with the swinging motion of the arm.

Another arrangement of an electric motor driving a countersinking machine is given in Fig. 4. In this case the motor is fixed on a wall bracket above the machine tool, and also drives through gearing. The full travel of the swinging arm takes place, the motor not interfering in any way with the motion of same.

For machines capable of countersinking holes up to 1¼in. diameter, the most economical horse-power to install is 5h.p., and motors of this output will be found to meet all requirements for such a machine. The action of this machine comes under the power conditions of constant speed and variable torque, the full power of the machine being utilised when countersinking is being performed. These machines are sometimes belt-driven, and this makes a most satisfactory drive. Where belt-driving is resorted to, the electric motor may either be placed on a wall bracket driving on to the pulley of the machine, or it may be fixed to the ground, driving in a similar manner; for the more satisfactory of these drives one has to consider the local conditions in each case.

Bending and Straightening Rolls.

Straightening rolls are one of the heaviest machine tools to be driven in the shipyard, and taking everything into consideration, the writer is of opinion that the most satisfactory drive for this machine is through belting. This is so, for the chief reason that in the working of this machine the point at which the heaviest stress acts is at the reversal and, as this is a sudden performance, with gearing a

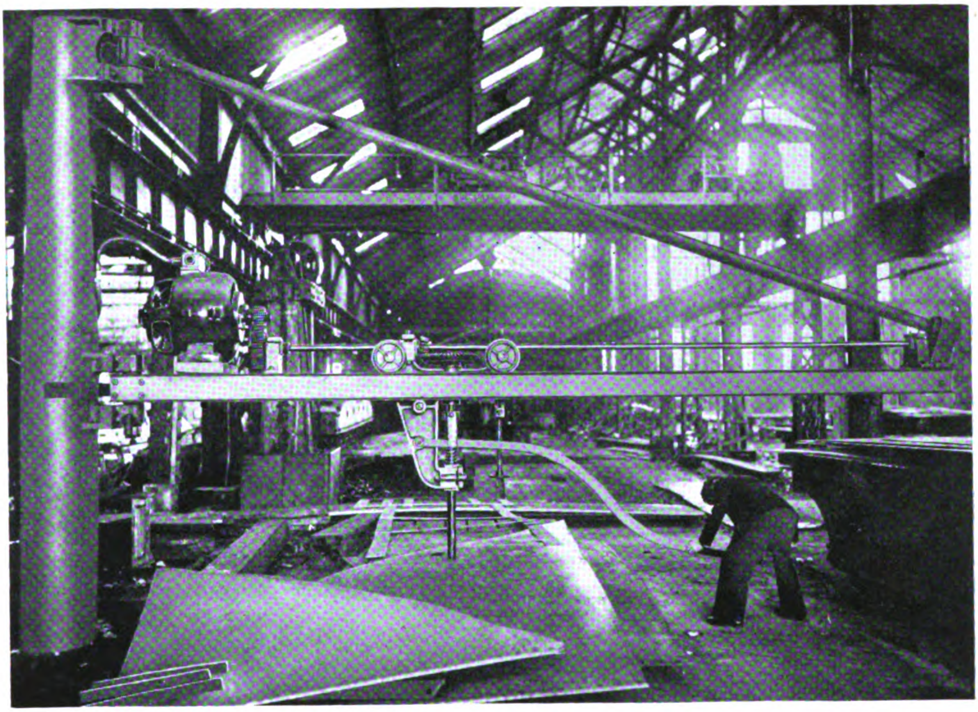


FIG. 3. COUNTERSINKING MACHINE WITH ELECTRIC MOTOR ON SWINGING ARM.

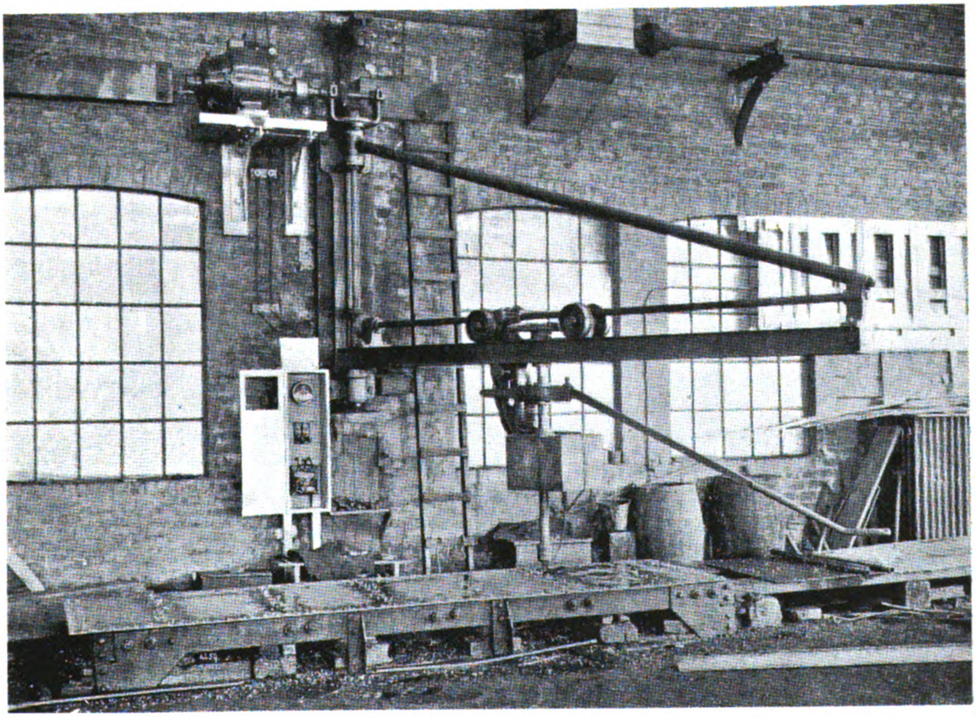


FIG. 4. COUNTERSINKING MACHINE WITH MOTOR ON WALL-BRACKET.

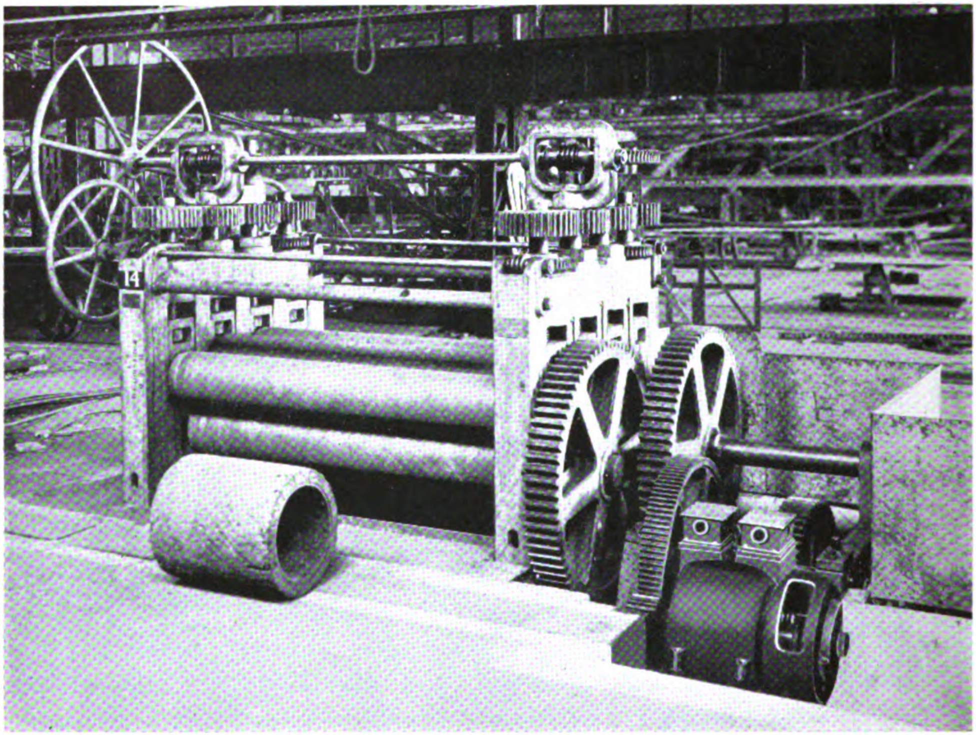


Fig. 5. Bending Rolls driven through Spur-gearing by Electric Motor and Fitted with Automatic Electric Brake Attachment.

very heavy strain on the motor is inevitable; with a belt drive, however, this sudden load is practically eased or taken off the motor by the momentary slipping of the belt. It is, of course, usual when an electric motor is driving such a machine through gearing to use an automatic magnetic brake, which, when the machine is reversed, automatically applies a brake to the motor and so stops it for the moment until the reversing action is completed. Fig. 5 shows such a machine driven through gearing and fitted with a magnetic brake action, while Fig. 6 illustrates a belt-driven machine. It will be noticed that in the latter case a structure of columns and girders was built, the motor being fitted to a sole plate fixed on the top of these girders. This method gives a clear ground space around the machine, which, in the majority of yards, is of the greatest importance. To drive bending and straightening rolls, the power required for say 7ft. rolls capable of dealing with ¾in. thick plates would be about 20h.p., while rolls of 30ft. taking 1¼in. plates and driven through gearing require to be fitted with motors of 35h.p. The author knows of at least one case where a set of 30ft. rolls capable of dealing with 1¼in. plates is being driven satisfactorily through belting by a 20h.p. motor. There is no doubt that when the reversing action takes place there is a most excessive overload on the motor, but as this machine is driven through belting the slipping of the belt relieves the motor from the full strain.

Plate-edge Planers.

Another machine tool with similar action to the foregoing is the plate-edging machine. In the older type of machine—that is, those having only the one cutting direction—the reversal of the machine occurs at light load, but whilst the up-to date tool cuts both ways, this really does not make any difference to the reversal, as at this point the only load on the motor is the driving of the machine tool, the actual cutting having ceased for the moment at the end of the stroke.

Plate-edge planers are always belt-driven and the power required for them is about 15h.p., which is capable of driving the largest size of machine tool of this type engaged in the planing of high-tension steel plates $\frac{3}{4}$in. thick with a tool speed of 17ft. per minute and a cut of $\frac{1}{16}$th of an inch. An illustration of a typical machine of this type arranged for the electric drive is given in Fig. 7.

The smaller shipyard machine tools, such as bar straightening and frame-bending machines, are driven in a similar manner, the motor, as will be seen from the foregoing details and illustrations, being capable of adapting itself to all conditions.

Manhole Punch.

There is one machine tool, however, viz., the horizontal plate-hole cutting machine for cutting manholes, which, in the writer's opinion, is most satisfactory when in the form of a hydraulic punch. Fig. 8 shows a machine for this service actuated by a 10h.p. electric motor driving through a Renold's chain and capable of cutting holes up to 30in. at a tool speed of 16ft. per minute.

Hydraulic Pumps and Compressors.

In shipyards there are many hydraulic and pneumatic tools which at present cannot very well be replaced by any other power, but the driving of the hydraulic pumps and the air compressors can undoubtedly be best arranged and most efficiently undertaken by electric power. Hydraulic pumps may be either driven through gearing or by belting to the electric motor; it would appear that the belt-drive is rather to be preferred. The use of gearing means that, if the motor is not stopped when the accumulator is charged, the motor and pump have to be continually working, and the pump, instead of charging the accumulator, simply circulates the water in the tank. The accumulator, having risen to its height, opens a bye-pass whereby the water is circulated.

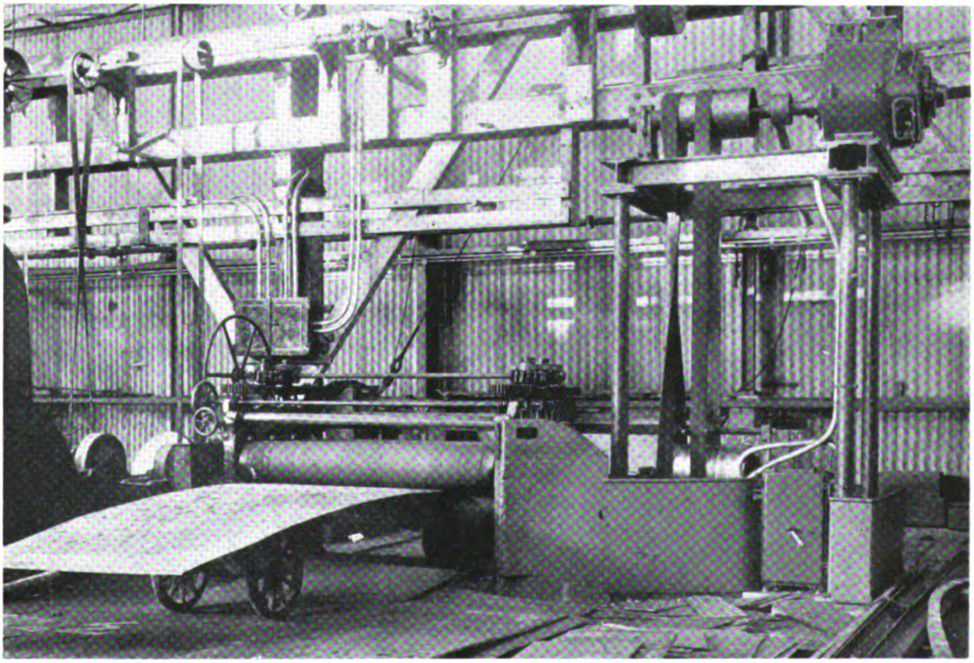


FIG. 6. BELT-DRIVEN BENDING ROLLS SHOWING ARRANGEMENT OF ELECTRIC MOTOR ATTACHMENT.

In a belt-driven machine, when the accumulator has risen to its height, the bye-pass opens to a cylinder fixed on the pump, and this, acting on the belt-striking gear, shifts the belt to the loose pulley. In this arrangement, there is a great saving in the wear and tear of the pump. No doubt it could be arranged that when the accumulator rises it could act in a somewhat similar manner on the motor-starting switch, but this is not altogether a simple problem to take up, and very special arrangements would have to be devised to ensure the gradual re-starting of the motor as required. Fig. 9 shows a set of hydraulic pumps driven by electric motors through gearing.

Air compressors may be driven and controlled in a similar manner to hydraulic pumps; whenever the receiver is at full pressure, the compressor, if it be belt-driven by motor, can either be stopped by the automatic arrangement of belt striking gear already mentioned, or the escape valve on the receiver may be allowed to blow.

Traction and Cranes.

We now come to the traction and crane gear of shipyards. There are many winches about shipyards, of which quite a number are still of the old type, most of them steam-driven and fed by donkey boilers, which consume great quantities of fuel. In an electrically-fitted shipyard these are without exception superseded by the electric motor winch, which is obviously far superior and which over and over again has proved itself unique in this service by reason of its economy and generally satisfactory working.

There is coming into use the electric trolley hoist, which is in some cases taking the place of the winch in yards where overhead cranes are not fitted, and there is no doubt that it makes for a greater rate of output of work and the minimum handling of material. A usual arrangement of these trolley hoists employs a long girder running down the centre of the building slip, supported from either side by cross girders carried on columns; the trolley and cab run on the centre girder, the whole operations of hoisting and travelling being effected by electric motors controlled from the cab. The wire carrying the current is

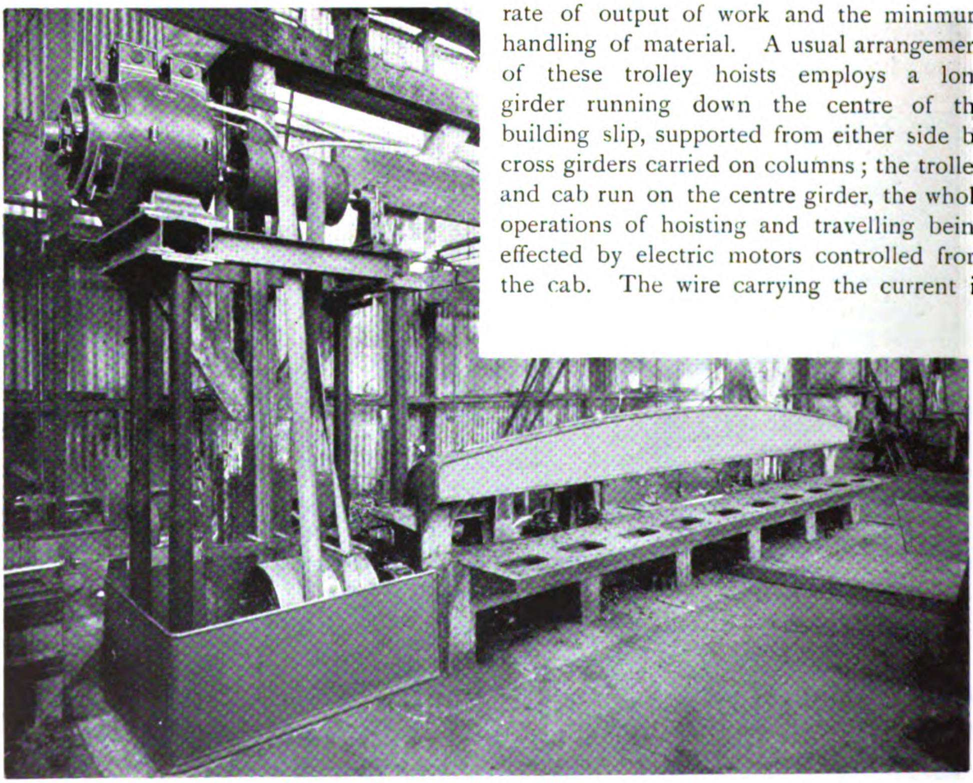


FIG. 7. PLATE-EDGE PLANER DRIVEN BY ELECTRIC MOTOR

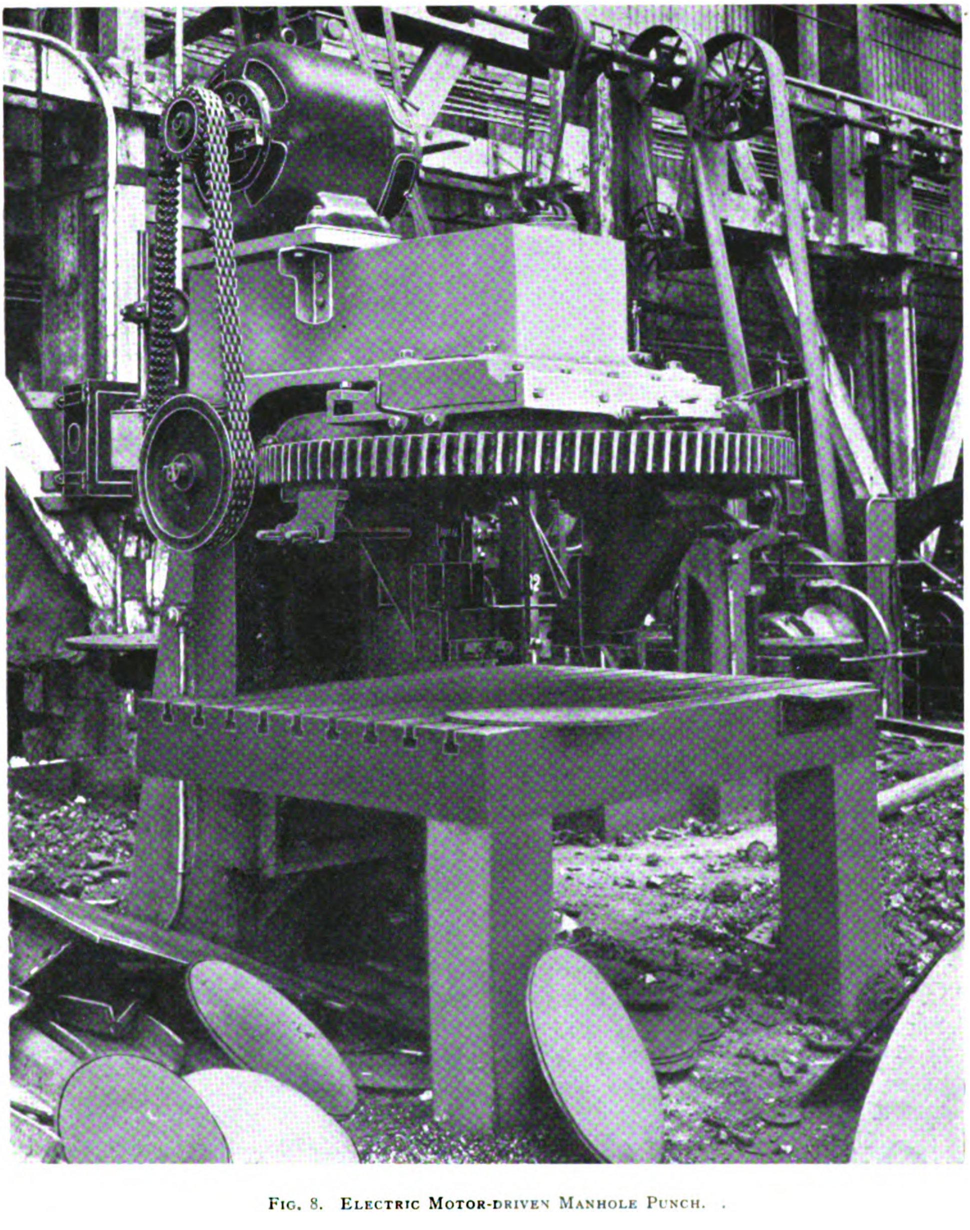


Fig. 8. Electric Motor-driven Manhole Punch.

run along the girder on insulators, and the contact is by trolley pole of the tramway type. These hoists are usually capable of lifting up to five tons.

There is no doubt that in shipyards, where the handling of material is a considerable item of expense, the transporter, once installed, will show a considerable saving in manual labour, and also in work done, and when fitted near to the discharging siding, a decided improvement in coping with angle bars, plates, and other material will be found.

Overhead travelling cranes fitted over

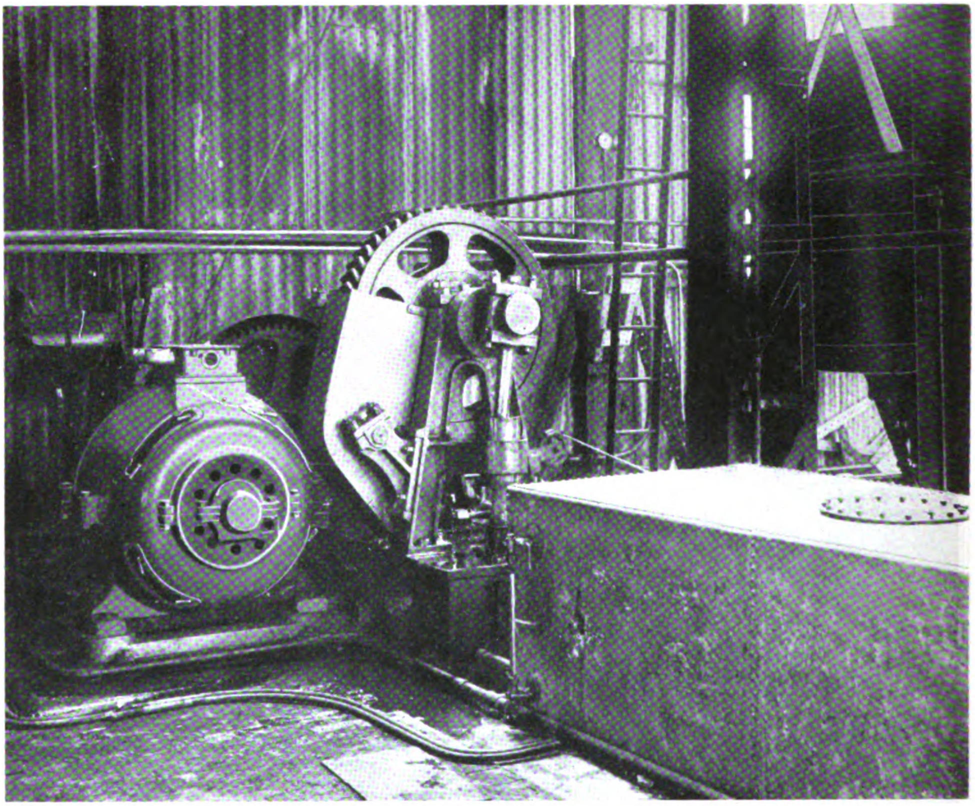


FIG. 9. HYDRAULIC PUMPS DRIVEN BY ELECTRIC MOTOR.

building slips in the larger yards are of great service, and not only over the slips, but in the machine shops of yards where the transporting of plates, &c., from end to end of the building takes place. These overhead travellers are usually fitted with three motors, each motion having hoisting, travelling and transverse motors respectively. The controllers are usually of the tramway type and all operations are worked from the cab of the crane. If desired they may be worked from the ground by a slight alteration in the type of controller. They are made up to various sizes and the power required for same is in proportion to the weight lifted. One of the most perfect installations of this kind consists of an overhead travelling crane fitted over a building slip in one of the largest yards. Below the travelling crane are four small walking cranes capable of lifting up to five tons; these run between the girder carrying the rail of the overhead travelling crane and another girder fitted to the structure. These auxiliary cranes are found most useful for putting the shell plates in place, and can be used while the overhead traveller is otherwise engaged. They are fitted with three motors—one for longitudinal travel, another for the hoisting motion, and the third for slewing, all operations being controlled from the crane.

The illustrations accompanying this article are of plants running in some of the largest shipyards of this country; they are all examples of work done by the General Electric Co., Ltd., to whom the author is indebted for the photographs used.

J. D. SHEARER.

THE SHIPYARDS OF PALMERS' SHIPBUILDING AND IRON COMPANY, LTD.

TYNESIDE and the Palmers' works are so closely identified that they must be regarded as inseparable. On the one hand Messrs. Palmers' Shipbuilding and Iron Company, Ltd., believe in making everything possible on Tyneside—they bring to Jarrow from Yorkshire, Spain, and Africa the iron ore and refine it themselves; they make their own steel, their own boilers, plates, engines, fittings, cabinet-work, and practically everything that goes to form a complete ship. On the other hand Tyneside is proud of Palmers'. Jarrow is Palmers' town; its first Mayor was the late Sir Charles Mark Palmer, Bart., M.P., who was the founder of the company and its chairman until he retired in 1893. Sir Charles was a Tyneside man by birth, he being born at South Shields in 1822; in 1851 he commenced shipbuilding together with his brother George under the title of Palmer Bros. & Co. After the retirement of his brother, the company was in 1865 formed into a limited liability company. In less than sixty years an unimportant colliery village has sprung into a closely packed industrial town boasting a hospital, theatre, technical schools and other institutions. The present works cover an area of about one hundred acres and have a river frontage of nearly three-quarters of a mile. They are connected by private line to the North Eastern Railway and with various collieries, and in the works themselves there are about eight miles of railway. From these works, on June 5, 1852, the first iron-built screw collier, the *John Bowes*, having a carrying capacity of about 650 tons, and capable of steaming at nine miles per hour, was launched. And this boat was the precursor of the large fleet of iron and steel ships which has since rendered Messrs. Palmers famous in the world. Fig. 1 gives some idea of the shipyard's present size and operations.

Power Generating System.

The electrical equipment of these works commenced over seven years ago to replace a great number of scattered steam engines and banks of boilers, when a Clarke-Chapman dynamo of the bi-polar type magnet construction was installed driven by a Sisson engine. The set was capable of giving 300amp. at 110 volts, when running at 490r.p.m. This was used for the electrical lighting requirements about the offices and yards. It soon became apparent, however, that it had to be used for power purposes, and for this reason a completely contained power station was erected, which equals in size many of the installations which are serving our smaller municipalities—two large sets, consisting of triple-expansion marine-type engines of about 1000h.p. each, running at 164r.p.m, drive 750kw. three-phase generators made by the Westinghouse Electric Company, of Pittsburg, U.S.A. (Fig. 2). These machines develop 984amp. per phase at a frequency of 30 periods per second, the voltage of the three-phase power supply throughout the works being 440 volts between phases. The armature is rotary, the field being of the projecting pole type, having 22 pole pieces, built up of soft-steel stampings, and to give uniformity in turning movement a 22-ton flywheel, 11ft. in diameter, is carried between the engine and the alternator by means of a flexible coupling. The fields of these generators are excited by means of current received from either of the two 6-pole Westinghouse generators of 25kw. capacity, giving 100amp. each at 250

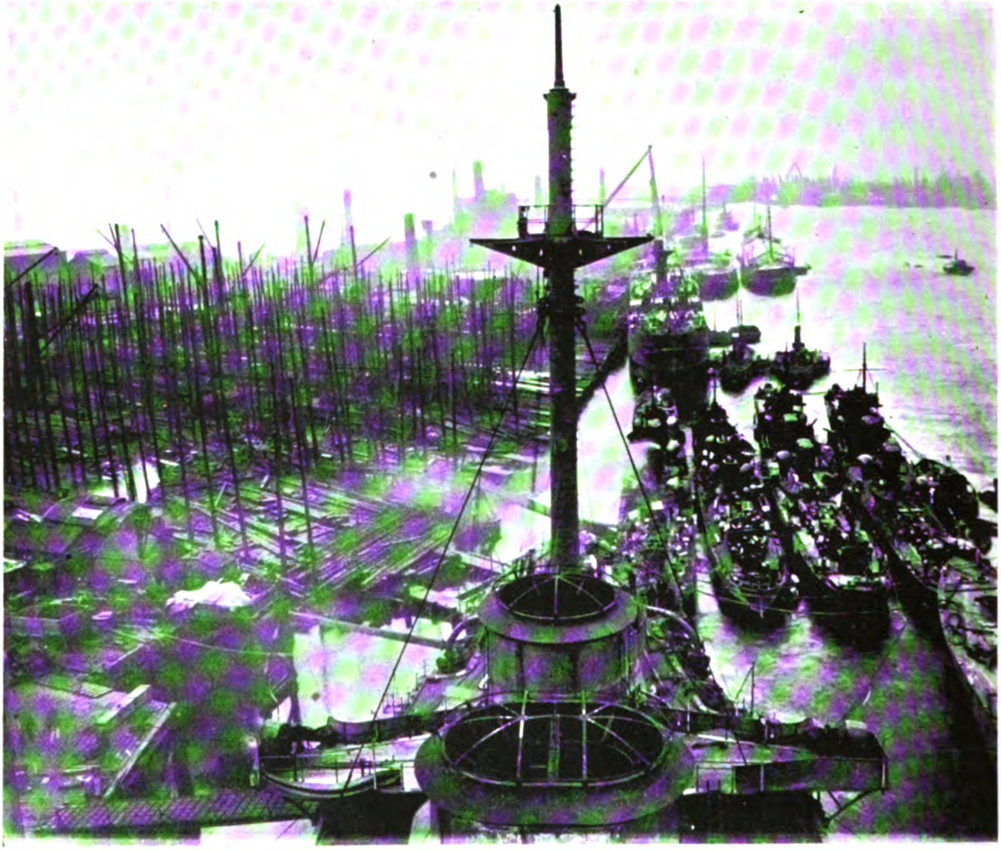


FIG. 1. GENERAL VIEW OF PALMERS' SHIPYARD.

volts. These are direct-coupled to vertical enclosed automatically-lubricated engines made by the Pittsburg firm, having cylinders 8in. and 13in. diameter by 8in. stroke, and running at 375r.p.m. These engines are interesting from the point of view of belonging to the pioneer period of enclosed high-speed engine building. The cylinders are single-acting and one steam valve works horizontally across the upper ends of the two cylinders.

As the lighting of the yards is laid out on the continuous-current system, it is necessary to feed from the generating plant by means of motor generators. In the power house are installed three motor generators, Fig. 8, made by the Lancashire Dynamo and Motor Company, Ltd. The three-phase motor is of 50h.p. capacity, running at 860r.p.m., and drives a generator giving 240amp. at 110 volts. The power house also contains two Alley & MacLellan engines driving the air compressors used on the pneumatic system throughout the yard. The steam requirements of the power house, both for the electric and pneumatic systems, are furnished by a battery of four Lancashire hand-fired boilers giving steam at a pressure of 150lb. per square inch. The feed pumps are Woodeson's patent vertical high-pressure steam-driven pumps, made by Messrs. Clarke, Chapman & Co., Ltd.

The main switchboard of the power house, Fig. 3, contains five marble panels, one being an exciter panel with the necessary switching arrangements for two exciters, together with two main generator panels for the main sets, and panels for dealing with the power circuits for the shipyard and the engine works, which have been recently equipped to manufacture marine-type engines and also turbines under the Parsons patents. Paralleling arrangements for the two alternators are provided. On the top of the board, which is placed against the end wall of the building, is the main fuse board for the power supply, containing twelve fuse blocks in four sets, placed in the main generator and feeder circuits. Incidentally it may be mentioned that the whole of the power system is adequately protected by fuses. The two large main circuits pass from the main board just described to main distribution boards protected by fuses in a similar manner, at which points the main circuits are split up into distribution board circuits. Finally, the distributing circuits are led to the motors. By this means faults on the circuits can be instantly located, and any trouble can be isolated without interruption to the main supply. Two small circuits are also run from this switchboard—one to the condensing water circulating pumps for the power house, feeding two direct-coupled centrifugal pumps driven by 40h.p. motors. These have a maximum lift of 15ft. at low water, and a head of 10ft. The other circuit passes to an auxiliary distributing board in the power house for motor circuits.

The direct-current main switchboard contains three generator control panels furnished with I.T.E. circuit-breakers having magnetic blow-outs, Ward-Leonard controllers, and Vulcan meters. Provision is also made to distribute the lighting to the general offices, the power station itself, and the docks. As an example of the distribution boards placed at convenient positions

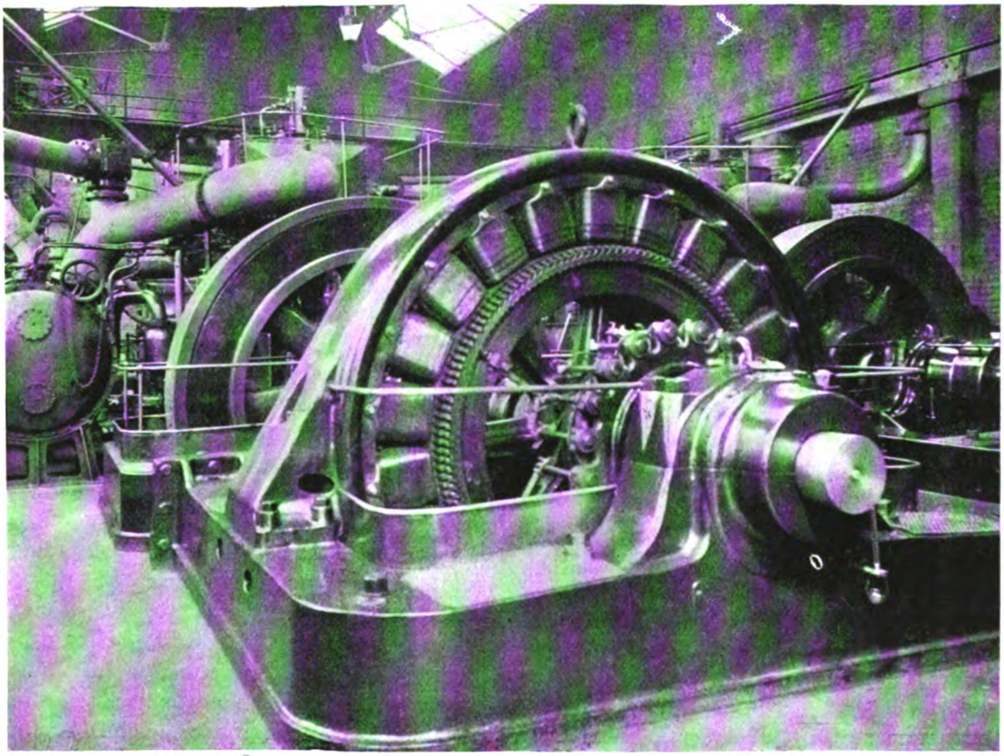


Fig. 2. The Three-phase Electric Generators at Palmers' Shipyard.

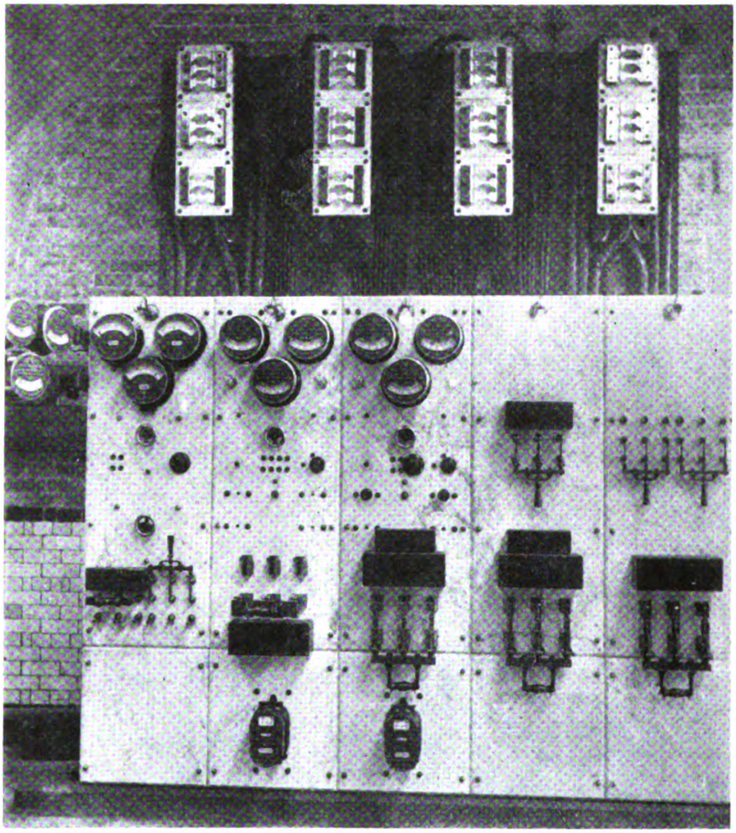


Fig. 3. Main Power House Switchboard.

throughout the yards, may be detailed the auxiliary switchboard above mentioned, installed in the power house for controlling five winch and other power circuits in the immediate vicinity. One circuit is for two 50h.p. dry-dock centrifugal pump motors, another for a 20h.p. winch for lifting stern posts, and another for a portable stern tube boring gear. On a slate base, protected by glass covers, are mounted for each circuit three-knife switches of the quick-break type, mechanically interconnected by wooden rods so that each phase of the circuit can be opened simultaneously. The assembling of the parts and the erection of the board were undertaken by Messrs. Palmers' own electrical department, which undertakes the electrical equipment of many of the ships built in these yards, together with the maintenance of the plant and the bulk of the electrical construction required in the yards.

Some three years ago it was found necessary—in view of the growing requirements of the yard, to provide additional electrical power. The ground space of the original power house was already fully occupied, and as the principal new requirements were centred in the reorganised joiners' shop at the eastern end of the yard, an auxiliary power house was erected adjacent to these shops and at the side of Messrs. Palmers' slipway. The object of this auxiliary equipment is to provide power on peak loads, and to run the night load of the station. The erection of a second overhead cableway provided an additional reason for the building of this station. The plant installed consists of a 300kw. three-phase generator built by the Lancashire Dynamo and Motor Company, Ltd., of the type shown in Fig. 4, having an output of 400amp. per phase at a voltage of 440 between phases and a frequency of 30 per second. It has a twelve-pole rotary field, formed of cast-steel poles, the tips of which are so formed as to give a near approach to a sine wave form, mounted on a cast-steel flywheel. The armature windings are embedded in partially-closed slots with protecting mica troughs. The machine, which carries 50 per cent. overload for one quarter of an hour and 20 per cent. for

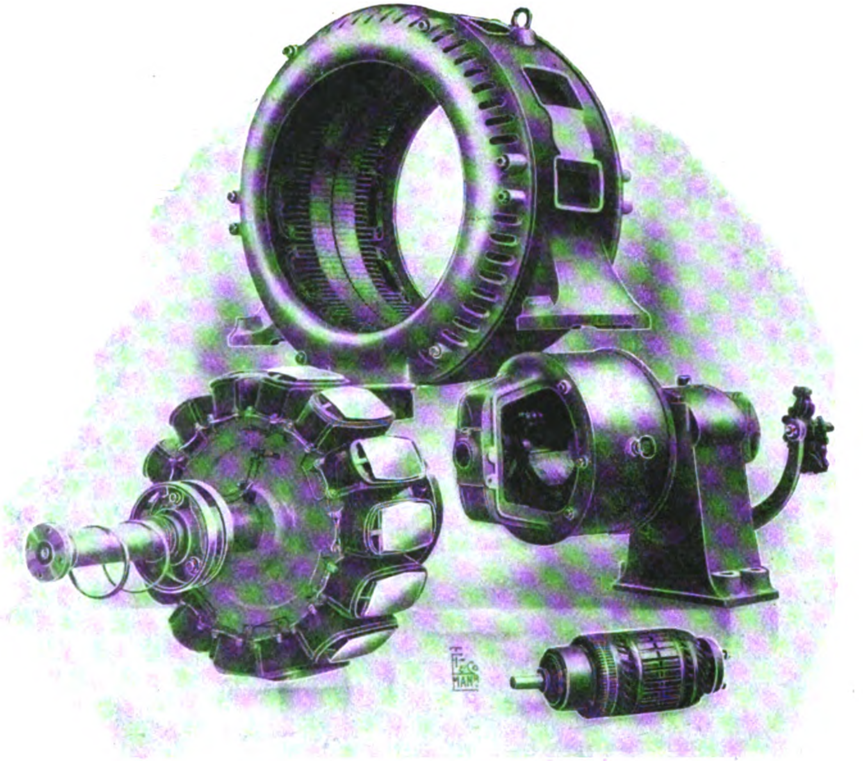


Fig. 4. Parts of the Three phase Generator in the Auxiliary Power House.

two hours, is direct-driven by means of an Alley and MacLellan triple-expansion enclosed-type engine with forced lubrication, running at 300r.p.m., giving 450b.h.p., with a steam pressure of 200lb. per square inch. The cylinders are 13in., 20in., and 31in. respectively, and the stroke is 13in. The valves are of the balanced piston type; the governing is effected by a throttle valve governor built on the crankshaft and directly controlling a balanced equilibrium valve; oil under pressure is supplied to all bearings and working parts at a pressure of 10lb. to 15lb. per square inch by a valveless oil pump. The exciter for the set, made by the above-mentioned firm, has its armature mounted on an extension of the main shaft, and gives 15amp. at 250 volts.

In order to provide steam for the set, a Babcock & Wilcox boiler, working at 190lb. pressure, and having a mechanical stoker made by Thos. Henderson, of Liverpool, is supplied. It is capable of burning not only coal, but all the refuse from the joiners' shop, effecting considerable working economy. The general arrangement of this stoker will be understood from the attached diagram, Fig. 5, showing its application to a Lancashire type boiler. The fuel, after passing through a receiver, is carried towards each furnace by helical rams driven by a simple arrangement of gear, and deposited upon revolving impellers, by which it is distributed over the furnace grates. The impellers are in constant motion, and a very regular distribution of the sawdust and

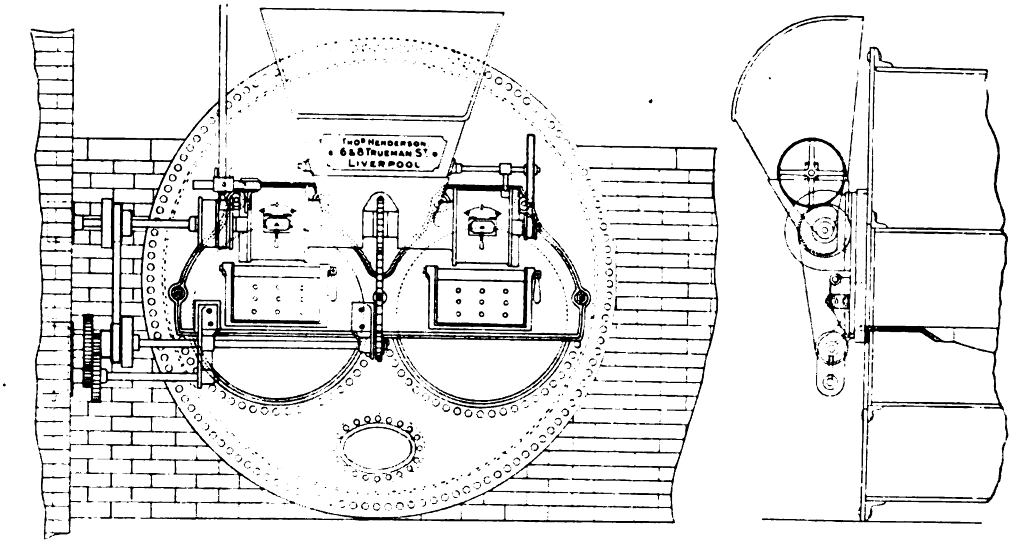


FIG. 5. GENERAL ARRANGEMENT OF THE HENDERSON MECHANICAL STOKER TO LANCASHIRE BOILER.

chippings upon the fire is obtained. Regulation of quantity is easily made, and as there is no necessity to open the firebox doors rushes of cold air to the furnace are avoided. A Green's economiser utilises the waste furnace heat to warm the feed-water, a steel chimney, erected by Messrs. Palmers, providing natural draught. Motor drive is adopted, both to drive the stoker gear—a ½h.p. three-phase motor being used—and also for the economiser scraper gear. The latter motor, with its fuses, is in the open air, being only protected from the weather by a sheet-iron case, and its continuous performance on intermittent work in a shipyard atmosphere is a satisfactory indication of the reliability of electrical gear. Make-up water for the boiler is drawn from the town supply, and the condensed water is purified by being passed through a water-purification plant made by Messrs. Harris, Anderson, & Co., Ltd., of Greenock, the feed pumps being of Messrs. J. P. Hall & Sons', Peterborough, patent compound direct-acting type, shown in Figs. 6 and 7. The exhaust steam is condensed in a surface condenser placed in a pit adjacent to the engine, and built by the Wheeler Surface Condenser and Engineering Company, of New York.

The main switchboard for this power house was built by Messrs. Palmers' electrical staff, and consists of four panels. The first contains the switches, rheostat, and instruments for controlling the exciter circuits; the second is the main dynamo panel connecting the machine to the station busbars; the third is the main distribution panel, which connects up the auxiliary station to the main supply; while the fourth is the joiners' shop supply panel. This contains in addition the main station meter, which is of the Westinghouse type. In order to parallel the two stations an Everett-Edgecombe synchroniser is provided, and in order to meet the condition of the auxiliary generator being shut down during the day, the joiners' shop can be fed directly off the distributing network of the yard through the auxiliary station board. Over the switchboard is located the main fuse board, as in the main generating station, fuses being placed in each phase of the auxiliary generator, the main power station supply and the joiner's shop circuit. At a point in the yard network so situated as to divide the load between the two stations in proportion to their capacities is placed a disconnecting switch, so that if necessary the two stations can be run entirely independently.

In order to provide lighting for this section

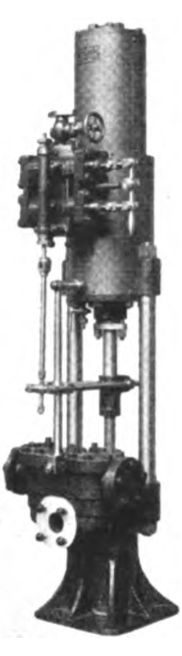


Fig. 6. Feed Pump.

of the yard a motor-generator made by the Lancashire Dynamo and Motor Company, Ltd., is provided, having a 40b.h.p. slip-ring motor running at 860 r.p.m. and driving a generator giving 240amp. at 110 volts. Fig. 8 shows the general appearance of this set, the motor of which is provided with a thoroughly ventilated stator, the stampings of which are of specially annealed charcoal iron to secure a minimum hysteresis loss. The rotor consists of a laminated core having the conductors placed in partially closed slots and insulated. The dynamo is of the Lancashire Dynamo and Motor Company's four-pole standard type, of very compact design. The field frame, of cast steel with laminated pole pieces, is split across the horizontal diameter for the ready inspection of the armature. The armature is of relatively large diameter with small armature reaction with slotted core and former-wound barrel-type windings. The brush holders are of this firm's patent "Box" type. The motor generator set is capable of standing heavy overloads if required, carrying 50 per cent. overload for a quarter of an hour, and 20 per cent. for two hours. The motor is operated by a Westinghouse auto-starter, while a board having a Whipp & Bourne magnetic circuit-breaker and Crompton ammeter and voltmeter is provided for the direct-current side. It may be mentioned that throughout the yard at convenient points there are six motor-generators for lighting purposes of the same general type and capacity, some of which have been already mentioned. The auxiliary generating station above mentioned has now been in commission about three years, running steadily from 5 p.m. to 5.30 a.m., besides intermittently throughout the day at times of pressure, and although the loads fluctuate very heavily, due especially to the working of the cableway motors, no trouble has been experienced in its performance.

Electric Motor Applications.

It may now be interesting to review some of the applications to which electric power

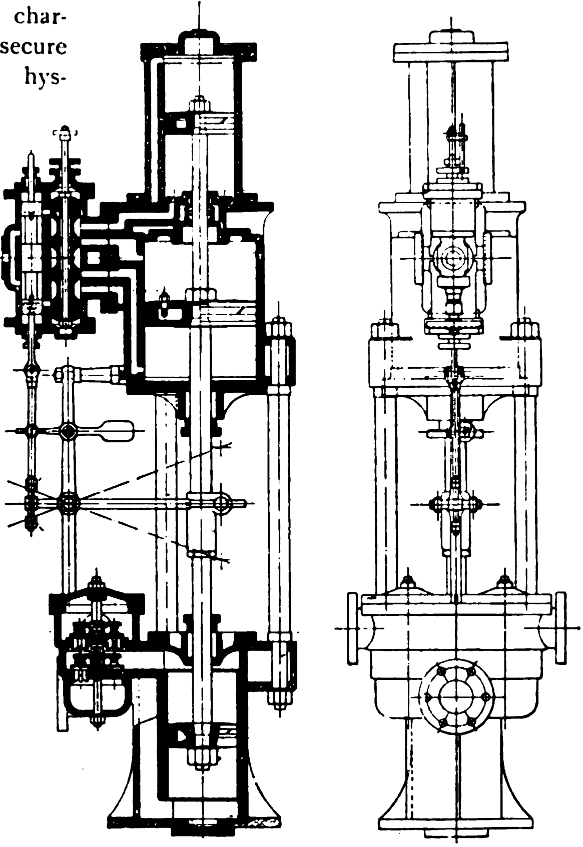


Fig. 7. Details of the J.P. Hall Feed Pump.

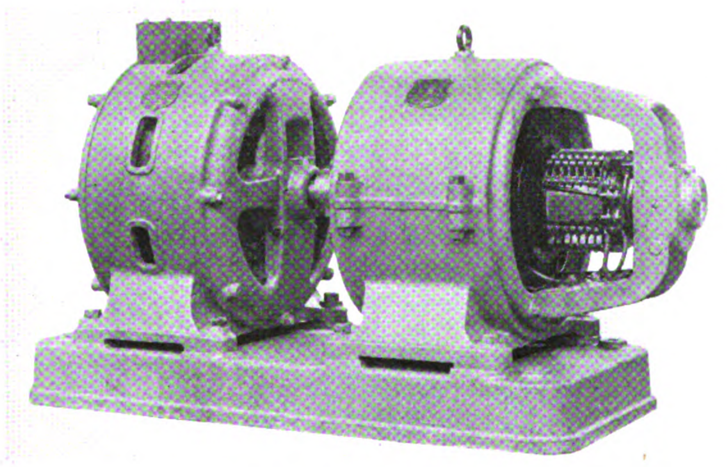


FIG. 8. THREE-PHASE TO DIRECT-CURRENT MOTOR GENERATOR FOR LIGHTING.

is put in these yards. The functions of a shipyard of such magnitude as this are very diverse, inasmuch as a considerable amount of subsidiary work, which would in smaller yards be sent out, can be more economically produced under central control when the growth of the firm renders the work of sufficient importance to be worth attending to. For this reason it would be impossible in the present article to attempt a detailed description of the various component processes in their relation to electric drive, and a general summary must suffice. One of the most important, because one of the most modern parts of the equipment, is the joiners' shop, which has been laid out on very sound lines. The building, which is self-contained, consists of a basement in which the motors are situated, over which is the ground floor, devoted to log-cutting, making deck planks, and other heavy work. Above this again a floor is used for the lighter joiners' machinery and the benches, while a well-lighted gallery and annexe on the top or second floor is devoted to the cabinet makers. The arrangement of the power drive in the basement is to have two motors, each of 50b.h.p., and each direct connected to a main shaft running transversely across the shop. From these shafts, belts are taken upwards to lines of machines on the ground floor. Another 50h.p. motor is installed to drive the machines in the top joiners' shop. Each of these motors is of the Westinghouse type, taking 68amp. per phase and running at 575r.p.m. with 30 periods frequency. In connection with a very complete sawdust exhausting system by Messrs. Adams, of Glasgow, a motor driving the fan is also situated in the basement. Each motor is controlled by an auto-starter, and these are collected into a well-lighted control room in the basement, so that the whole of the joiners' shop can be started from

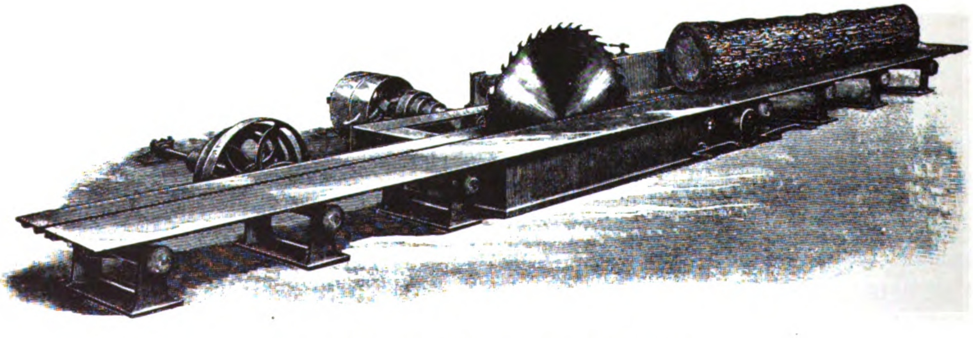


FIG. 9. SELF-ACTING CIRCULAR SAW RACK BENCH.

one point. Over each starter is placed a set of fuses, one for each phase, in the motor circuits, while a portion of the lighting of the building is also controlled from this point. The woodworking machines on the ground floor include a series of heavy tools by Messrs. John McDowall & Sons, of Johnstone, N.B., including a heavy saw frame for taking logs up to 36in. diameter, and adapted for all kinds of round or square timber. The motion to the sawgate or working frame is conveyed by two connecting rods holding the frame near its centre, driven from a disc crank connected to fast and loose pulley arrangements. At full rate of work about 45b.h.p. is required for this machine alone. Another fine machine is a self-acting circular saw rack bench, Fig. 9, with a travelling table of steel plates, and carrying a six-foot saw running at 500r.p.m. This is used for cutting deck planks and similar stuff up to 40ft. long, and absorbs about 40b.h.p. Other machines are a deal frame planing machine operating on four sides of the timber at once if required, at speeds up to 70ft. per minute; and a four-cutter moulding machine. On the floor above there are such machines as small circular saws, band-saws, mortisers and borers, irregular moulders, &c., by the same firm. On this floor is located the auxiliary power and lighting distributing board for the joiners' shop, constructed by Messrs. Palmers' electrical staff. On the top floor is situated the tool room of the department, containing among other things a good grinding equipment by

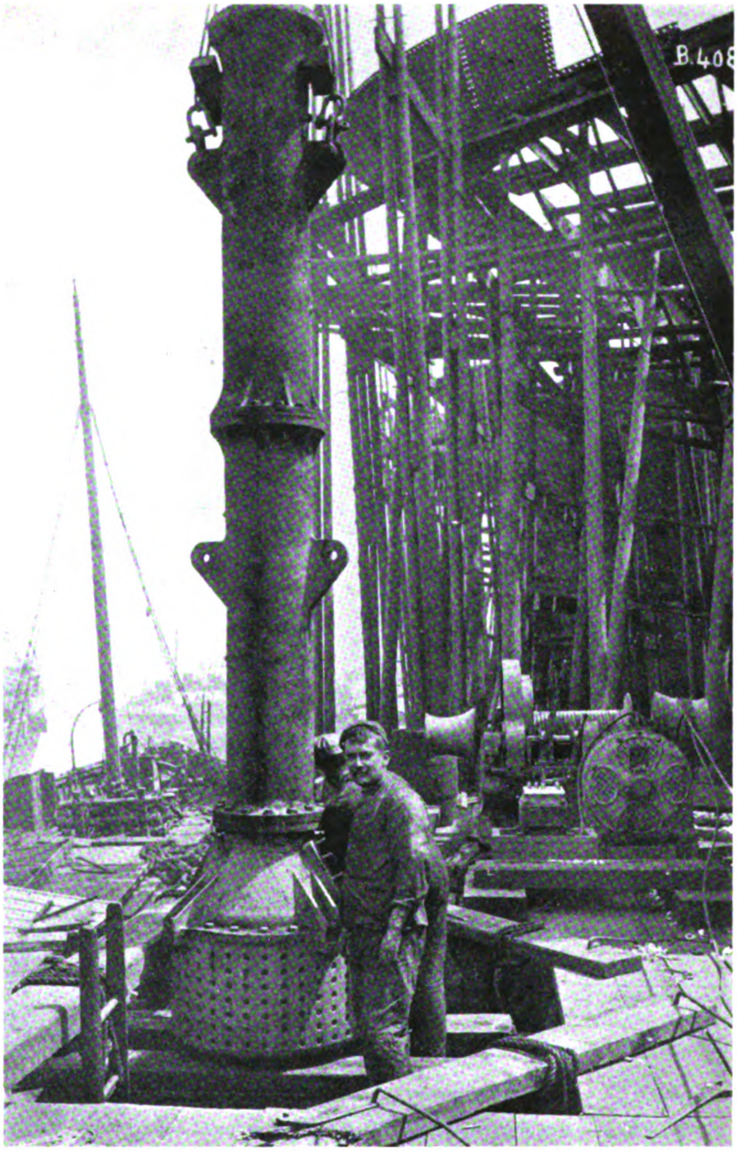


Fig. 10. Clarke-Chapman Electric Winch.

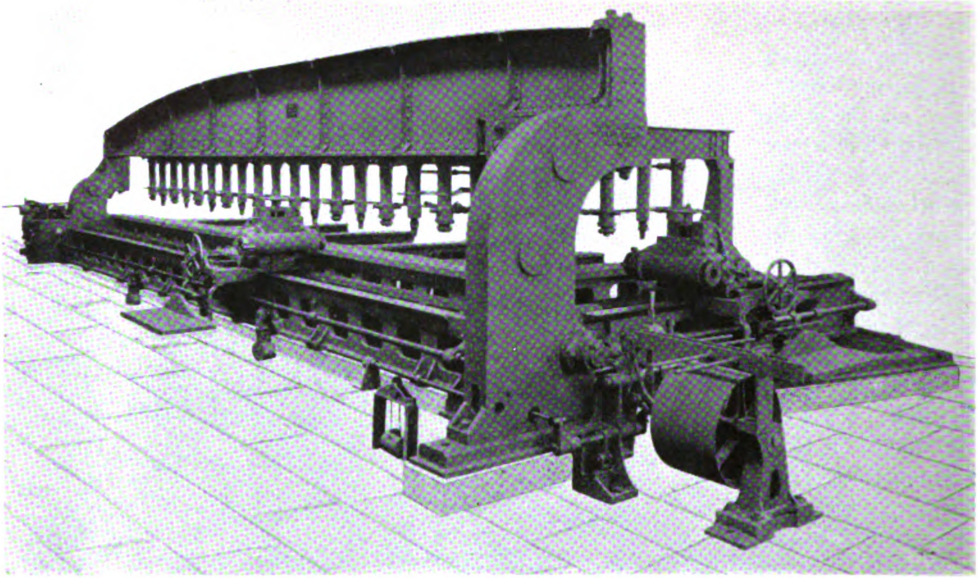


FIG. 11. PLATE EDGE PLANING MACHINE.

Messrs. John McDowall & Sons, for saw sharpening, grinding, moulding cutters, filing and setting saws, &c., driven by a 5b.h.p. motor. The building is 196ft. long and 76ft. wide.

On the other side of the auxiliary power house to the joiners' department is the slipway, which is 600ft. long, and capable of dealing with vessels up to 1600 tons. The vessels are drawn up the slipway by a hydraulic ram, and the water for this is pumped electrically, the three-throw horizontal ram pump being operated by a 40b.h.p. induction motor having automatic starting and stopping gear operated by the position of the accumulator. For warping purposes and incidental work the slipway is equipped with electrical winches made by Messrs. Clarke, Chapman, & Co., Ltd, of Gateshead, and these are generally used throughout the yard and in the berths (Fig. 10). It may here be mentioned that all motors throughout the equipment up to 20b.h.p. capacity were made by Messrs. Clarke, Chapman, & Co., Ltd., larger sizes being supplied by the Westinghouse Company.

The buildings in which the main part of ship constructional work is done are divided into three long sheds, roofed in, but for the most part open at the sides to allow free handling of large plates and girders used in modern ship-building. In these some very fine examples of heavy ship-building tools may be found, among which may be mentioned a large double-ended shear made by Messrs. Craig & Donald, of Johnstone, N.B.; double-ended punches and shears by Messrs. A. W. Smith & Co., of Glasgow; edge planing machines—one 40ft. long—by Messrs. Hugh Smith & Co., of Possil Works, Glasgow (Fig. 11); and a series of machines by James Bennie & Sons, of Cardonalds, near Glasgow. One of these is illustrated in Fig. 12, showing a punching and shearing machine of the three-sided type, which is capable of punching 1½in. holes through 1½in. steel plates at one end, shearing 1½in. plates at the other end, and punching out manholes up to 16in. diameter at the side. The machine is provided with self-contained cranes to carry plates up to three tons in weight, and, as shown by the photograph of the machine taken at the shipyard after erection, is a particularly fine specimen of machine tool work. No. 3 shed also serves the purpose of a screeving loft, a very large

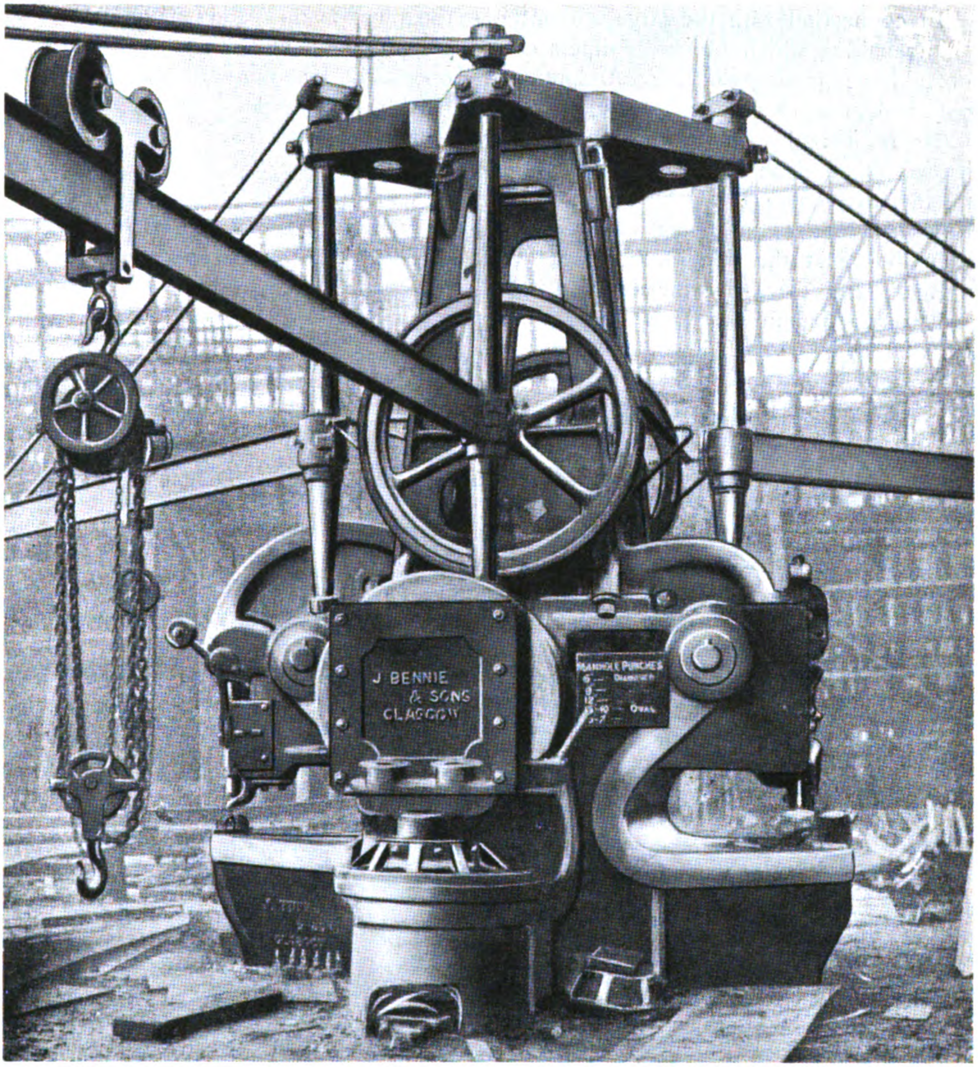


FIG. 12. LARGE THREE-ENDED PUNCHING AND SHEARING MACHINE.

floorplate being installed on which the various portions of vessels built by the firm are laid off. This shed is also interesting as being the place where the individual electric drive of machine tools is largely adopted; in the other sheds the machines are group-driven by means of four motors ranging from 30b.h.p. to 50b.h.p., through shafting and belting, but here the motors are mounted directly on the machines, examples of this arrangement being found in the drive of plate bevelling machines by Davies & Primrose, of Leith, and a large squeezer for bending angles, made by J. Bennie & Sons. Provision is also made in these sheds for the installation of a switchboard, made by Messrs. Johnson & Phillips, Ltd., of Charlton, Kent, for controlling the supply of three-phase power to the two large overhead cableways—which form such a conspicuous feature of these yards, and which will be described later—together with the distributing boards for the power circuits of the sheds themselves.

In connection with the large amount of ship repairing which Messrs. Palmers carry on, a large graving dock, 440ft. long and 70ft. wide, occupies a central position on the water front and near to the main power house. The dock is pumped out electrically, two 50b.h.p. Westinghouse motors running at 575r.p.m. being installed in a pump-house at the side of the dock (Fig. 13). These drive by means of vertical belts on to medium-speed centrifugal pumps situated some 20ft. below the floor level. The motors, of the slip-ring type, are controlled by auto-starters of the Westinghouse pattern. There are no drainage pumps, as it is found that the docks can be kept sufficiently dry by the occasional running of the main pumps. The installation was made some seven years ago, and it has proved very successful in operation. The dock is closed by means of a floating caisson which, although at present pumped out by steam, is shortly to be equipped electrically, a 50h.p. motor being installed for that purpose. At the bank-top adjacent to this dock is a line of six shearing and punching machines for the purpose of dealing with plates used in construction, and these are individually operated by motors mounted on the machines themselves. As they are exposed to all conditions of weather, the motors are iron-cased, and the switchgear has to be of particularly sound construction. The switches used are of the "Stellite" iron-clad pattern, made by the Electric and Ordnance Accessories Company, Ltd., of Birmingham.

Electric Overhead Cableways.

Every shipbuilder will know that in 1905 Messrs. Palmers introduced what was practically an innovation in shipyard equipment by erecting the first of their two gigantic overhead cableways, and in view of the fierce discussion which then arose as to the wisdom of such a step the foresight of Mr. J. L. Twaddell, the manager of Messrs. Palmers' Shipyard Department, is very greatly to be admired. The system adopted in the first design was the suspension of three cableways lengthwise over the building berth from two cross-girders, each lifted to a height of about 100ft. above ground by two inclined

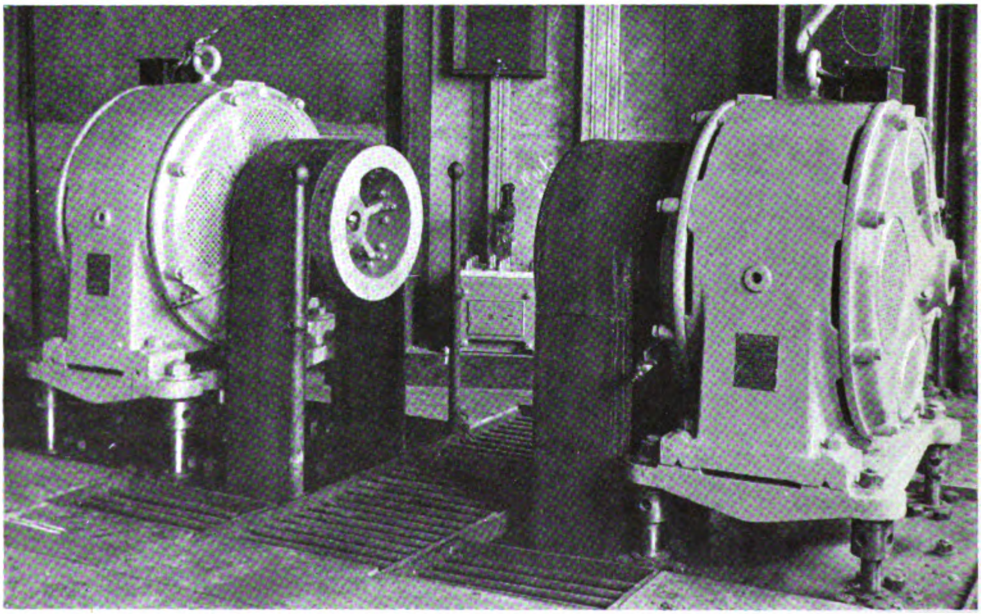


FIG. 13. TWO GRAVING DOCK PUMP MOTORS.

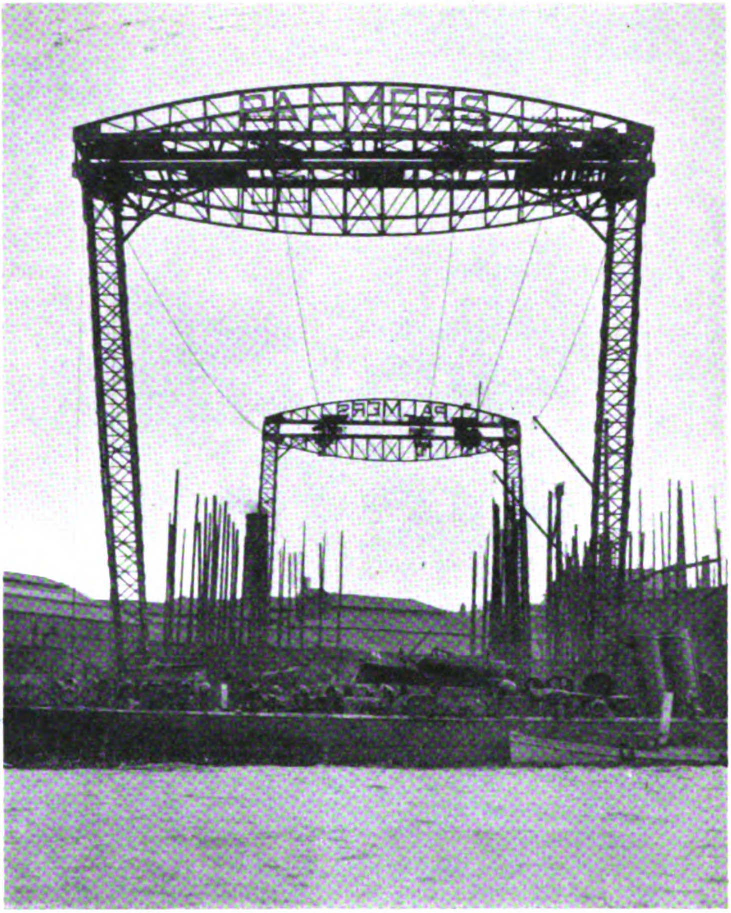


Fig. 14. General View of Electric Overhead Cableway

lattice-work columns. End carriages to which the cableways are attached travel transversely along these cross-girders. Each of the four concrete foundations for the columns measures 16ft. square at ground level, and weighs about 140 tons. Back guys drop vertically from the heads of the columns to concrete anchorages, and the columns are pivoted at their base. The area covered by the cableway is 500ft. long by 100ft. wide, and the sag of the trolley cables in 500ft. is about 18ft. There is a fall towards the river in conformity with that of the ground, so that when material is being fed from the head of the berth the heavy truck is helped to its destination by gravity, so that current is on the whole saved. The end traversing carriages, six in number, are each propelled by a 12b.h.p. ventilated enclosed reversible motor geared through worm and spur gearing to two axles carrying the rail wheels. The motors on both end carriages are controlled simultaneously in either direction by the operator from the load carriage. On the main cables, which are each 7¾in. in circumference, having an ultimate breaking strain of 175 tons, run the fore and aft trolleys or load carriages, constructed of steel with suitable cage for the operator. In each of these carriages is a 35h.p. motor, which performs the hoisting and travelling motions. The longitudinal travel is obtained through friction and spur gearing from motor to travelling motion shaft. On this are keyed two rope drums, over which pass ropes which are anchored at each end of the cableway. The hoisting motion is obtained through friction and spur gearing to a drum running loose on a hollow steel shaft. Mechanical friction brakes are fitted to both motions, and the current is conveyed to the motors from overhead copper cables, suspended between the supports, through collecting arms. The electric cables are attached at each end to steel spiral springs in compression, and should a live wire break on any of the phases, automatic cut-outs act. Two controllers, one for the load carriage motor and the other for the end carriages,

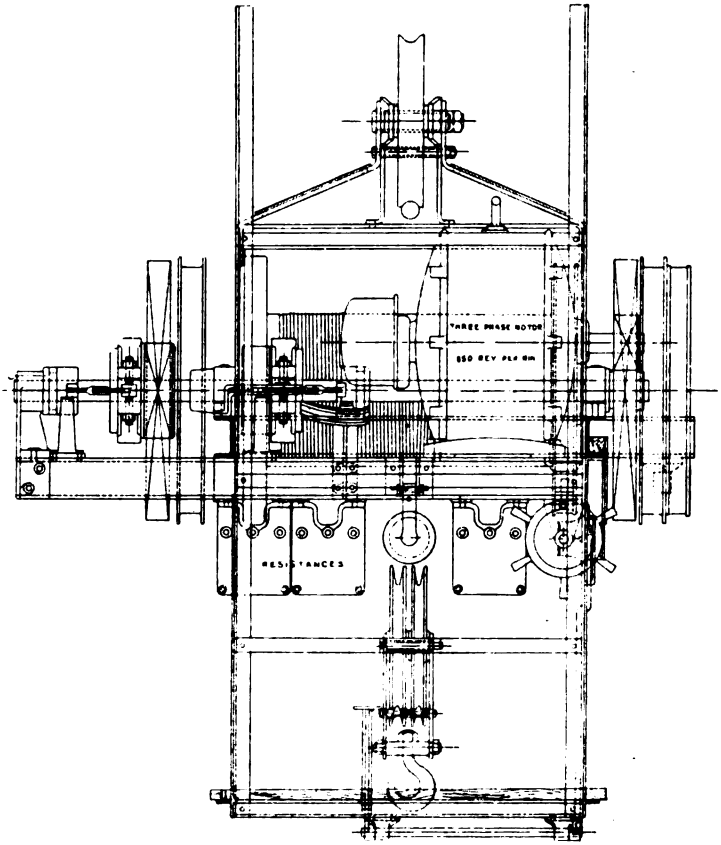


FIG. 15. DETAIL OF FORE AND AFT TROLLEY OF CABLEWAY.

are placed in the cage, a second set of wires for the latter leading back from the controller to the motors. The usual speed of travel longitudinally is 400ft. per minute, though 600ft. can be obtained; the traverse speed is 25ft. per minute, while for hoisting three tons can be lifted at 100ft. per minute, or one ton at 150ft. per minute by each hook. The cableway was patented and constructed by Messrs. John M. Henderson & Co., of Aberdeen, while the motors of the three-phase enclosed slip-ring type were supplied by the Lancashire Dynamo and Motor Co., Ltd. So successful was this cableway in practice that about eighteen months later a second cableway of larger dimensions but of similar type was put into operation. This covers a rectangle of 700ft. by 150ft., or two building berths, and is served by four cableways. In this case the electric cables are grouped around a steel wire rope from which they are supported at intervals of about 76ft. to 80ft. Fig. 14 shows the general appearance of one of these cableways, while the drawings (Figs. 15 and 16), published by permission of the Institute of Naval Architects, give a detail of the fore and aft trolley on the first cableway constructed.

General Electric Applications.

In connection with shipyard work there are a large number of miscellaneous trades which depend upon the main industry, and in connection with an undertaking of the size of Messrs. Palmers Shipbuilding and Iron Company, Ltd., it is economically preferable to group all these trades under one management. Accordingly space is given in these yards to foundries for iron and brass, a pattern-making department, the shipyard forge, fitting shops, plumbers' and riggers' departments. In all these the electric drive is used to a greater or less extent. In the metal foundry, which is one of the older portions of the yard, an instructive lesson is learned as to the advantages of electricity for crane operation. There are two electric travelling cranes working side by side with three steam-driven cranes of the same description, and the sight of the donkey engine and boiler suspended in mid-air, together with the liability of red-hot cinders falling on the men beneath, enforces its own moral. In this department a

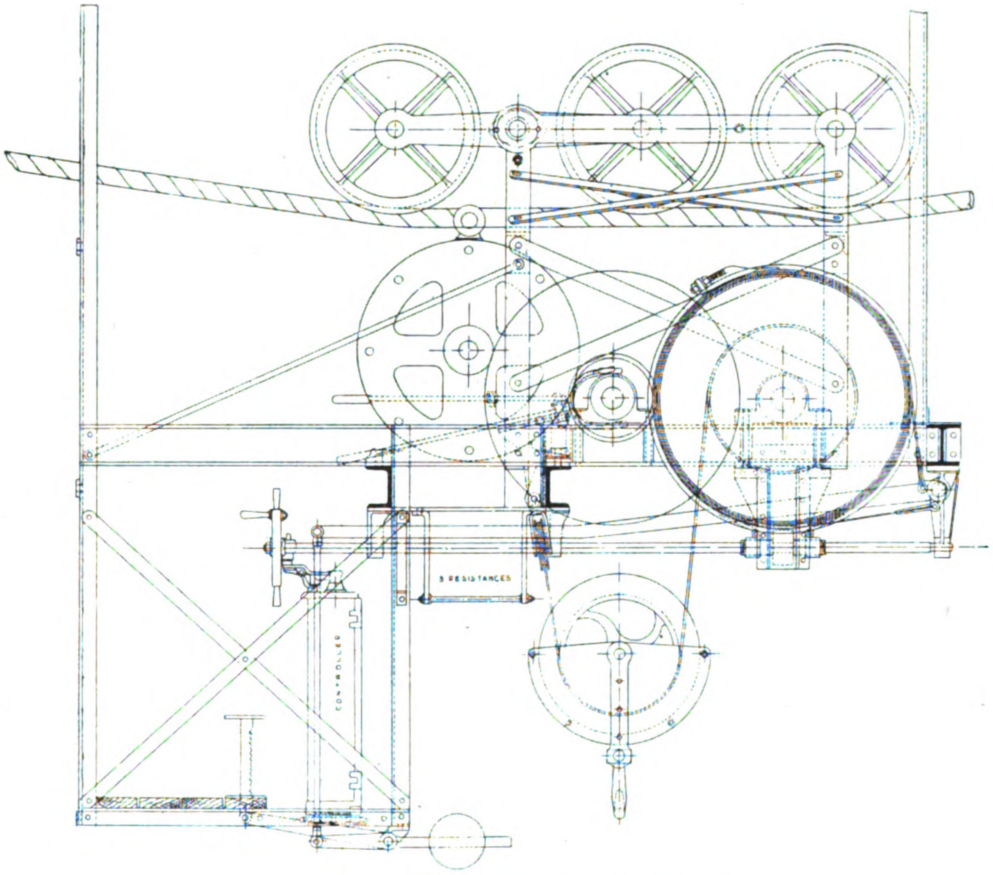
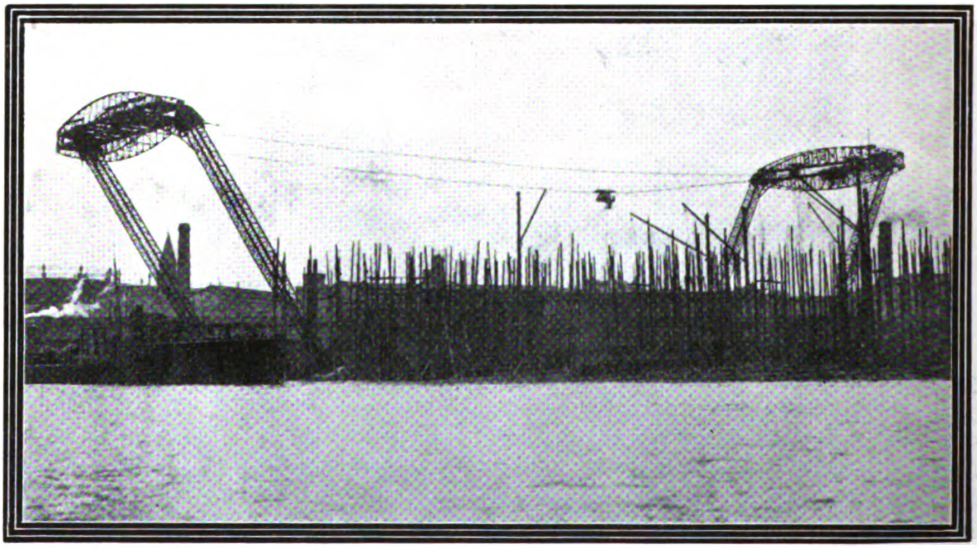


FIG. 16. DETAIL OF FORE AND AFT TROLLEY OF CABLEWAY.

50b.h.p. motor drives pug-mills for preparing the sand and a Sturtevant fan for the cupola blast is also electrically driven. In the brass foundry two motors are used, one for driving an electric travelling crane by rope gearing to the motions, and the other operating a line of shaft for miscellaneous tools. Adjacent to these departments is the metal-breaker, the monkey for which is lifted by a 5h.p. motor. In the shipyard forge there are four 20-ton cranes made by Messrs. Craven Brothers, Ltd., having a light and heavy lift and fitted with a four-motor equipment, while a 15b.h.p. motor drives the fan for the forges. In addition to a large number of ordinary open-hearth fires there are two large floor forges for the purpose of taking heavy work such as stern frames, &c. The hammers are all steam driven. An electrically operated winch and a pair of shears for cutting scrap iron are also provided. An 8h.p. motor is installed in the plumbers' department for the general work of this shop, such as pipe-cutting and screwing, while in the fitting shop two main lines of shafting driving engineering tools such as lathes, drills, &c., are operated by a 50b.h.p. and 30b.h.p. motor respectively. A special motor room is built to contain these machines, and one of the lighting motor-generators previously mentioned is installed here for the needs of this section.

In addition to the activities detailed above, Messrs. Palmers Shipbuilding and Iron Company, Ltd., have, as their name to some extent indicates, for a long time produced for themselves and other manufacturers iron and steel at extensive works closely adjoining the shipyard. In addition to this they have recently laid down a thoroughly modern and complete plant for the manufacture of marine engines and turbines, the latter being under Parsons' patents, in order to be in a position to undertake the complete main construction of any class of steel vessel, from the "tramp" to a battleship such as the *Lord Nelson*, which was recently launched from this yard. The description of steel manufacture and turbine building does not enter into the scope of this article, and it is hoped, in a further number of THE ELECTRICAL MAGAZINE, to give some interesting particulars of Messrs. Palmers' work in this direction. The author has, however, in the present instance the pleasure of putting on record his sense of the courtesy of Mr. Malcolm Dillon, the secretary of the company, and Mr. J. L. Twaddell, the manager of Messrs. Palmers' shipyard, in allowing him to carefully examine their electrical equipment, and in assisting him in the preparation of technical particulars concerning its application to shipbuilding.

J. A. SEAGER.



THE OVERHEAD ELECTRIC CABLEWAY AT MESSRS PALMERS'.

THE ELECTRIC LIGHTING OF STEAMSHIPS.

(*Specially Contributed.*)

LIMITATIONS of space will prevent this article being more than an outline of the methods adopted in applying electricity to ship-lighting service. The requirements for different classes of vessels—for instance, battleships, liners, private yachts, passenger and cargo steamers, oil tank steamers, and steam trawlers—are so varied, that only one or two of the more frequently used methods can be described in detail.

Electric lighting is *the* method *par excellence* for ships, and it may be safely said that practically every steamship built within the last fifteen years or so has been fitted with an electrical installation.

When the use of electric light first became general on board ship, the "single-wire" system was employed to a large extent. In this method of wiring one main cable and one branch main only, instead of the usual pair, are used, the "return" being through the framing and plating of the ship. One terminal of the dynamo is of course also connected to the ship.

The branch wiring in the cabins and accommodation is sometimes also "single

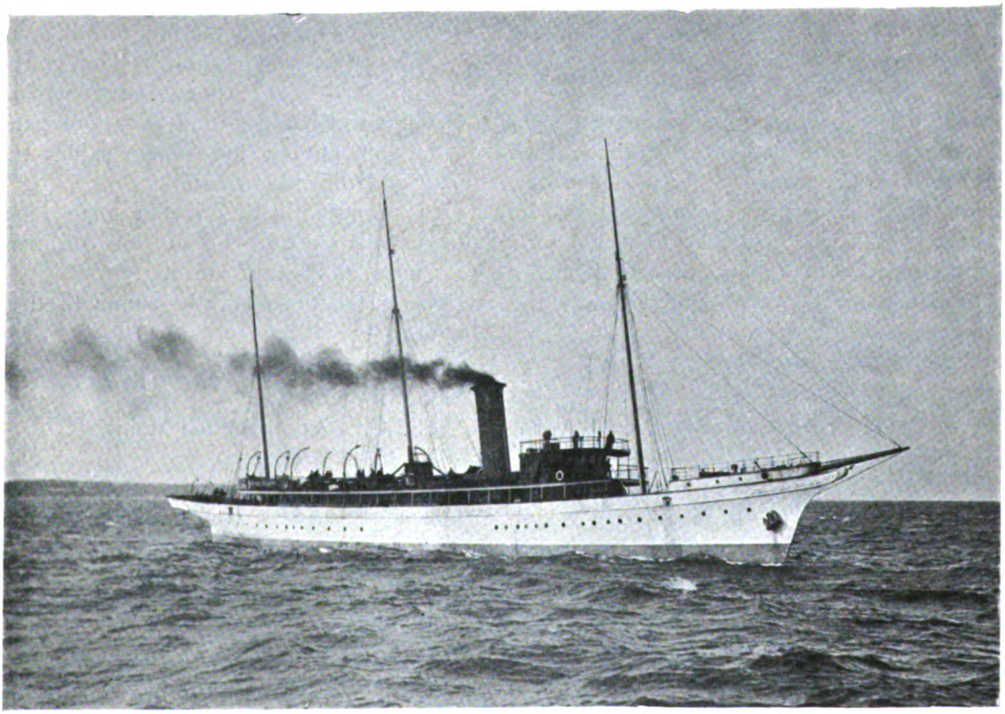


FIG. 1. SIR GEORGE NEWNES'S T.S.Y. "ALBION."

The Electric Installation on this Yacht, which was completed in 1905, includes 157 lights with plugs and sockets for Portable Lamps and Radiators in State Rooms, Owner's Quarters, Smoke Rooms, &c., Wiring for Steering Gear, Winch, Windlass, Refrigeration, Ventilation, Forced Draught, Bells, Projector, &c.

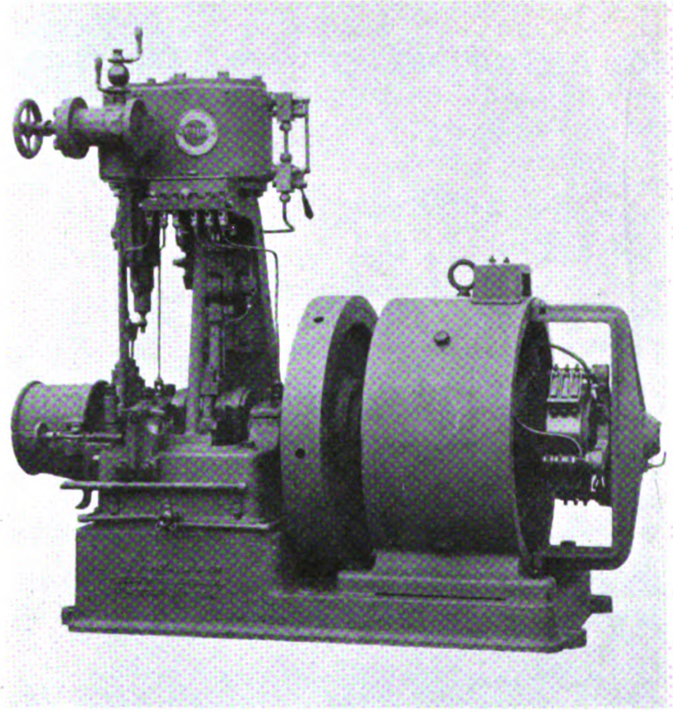


FIG. 2. SHIP-LIGHTING SET: SINGLE-CYLINDER OPEN TYPE ENGINE.

wired," but in many cases it is more convenient to use the ordinary "double wire" system in these parts of the ship. Further, in the deck houses near the bridge and wheel house it is considered safer to use double wiring on account of possible electromagnetic interference with the readings of the compasses.

The "single-wire" system is still used, though not to the extent that it was some ten or more years ago. Several of the large steamship companies still adhere to it, and will have nothing else on any new vessels built for them. The advantages are a considerable saving in the cost of mains and branch mains, and a 50 per cent. saving of armoured wires in the engine and boiler rooms, tunnels, &c. There are also fewer connections to the distribution and main switchboards, and a less number of small branch wires for faults to develop in.

The "single wire" and other similar systems, such as concentric wiring with an uninsulated return, have been superseded by the ordinary "double wiring," as in land practice, to a large extent.

For many years, the usual voltage for ship work was 60 or 65 volts; this has given place to 100 volts, which is now the generally adopted pressure. The Admiralty, however, formerly used 80-volt circuits, while their most recent practice is to use 220 volts.

Most of the latest battleships are so equipped, on account of the increasing use which is made of motors for all purposes. The consequent large amount of energy to be transmitted to various parts of the ship renders low-voltage cables too bulky and difficult to handle.

It is proposed to describe in some detail the installation fitted on an ordinary passenger and cargo steamer.

The installations may be summarised as follows:—

Engine and Dynamo.
Main Switchboard.
Main Cables and Branch Mains.
Section Fuse Boxes.
Branch Wiring.
Fittings, Switches, and Lamps.
Distributing Fuse Boxes.

Engine and Dynamo.

The engine may be either of the open or enclosed type; the former usually running at speeds of from 250r.p.m. to 400r.p.m., while the latter is usually made for 500r.p.m. to 600r.p.m. The higher-speed plant naturally can be made lighter and smaller for a given output than the lower-speed one.

The lubrication of the open-type engine is effected by a single oil box, with pipes, sight feeds, and separate adjusting cocks to all the working parts. The supply of oil can be cut off by one master cock when the engine is not required, without interfering with the adjustment of the individual supply pipes and cocks.

An "enclosed" engine is usually lubricated by the "splash" method, the crank chamber being kept rather less than half full of oil and water, into which the cranks dip at every revolution and splash up the mixture to all the working parts. In some types of enclosed engine, however, forced lubrication is adopted, a small oil pump being driven by the shaft, and supplying all the bearings with oil under pressure, through a pipe system.

The speed regulation of engines is effected by governors of the flywheel type, in which the eccentric sheave is moved on the shaft by weights disposed within the flywheel, and thus altering the "cut-off"; or by means of a throttle governor valve, actuated by moving weights mounted on the crank shaft.

Belt-driven throttle governors are to be avoided, owing to the risk of accident through belts breaking or coming off. The throttle governor driven direct from the crankshaft has the advantage over the automatic cut-off type in that the speed can be varied by hand while the engine is running.

A well-designed coupled plant for ship-lighting should not vary more than about 5 per cent. in speed from no-load to full-load, and the dynamo should preferably be over compounded to a rather large percentage, to compensate both for drop in engine speed and the C^2R losses in the main cables.

The dynamo is usually of the multipolar type, and compound wound. In well designed machines, fitted with carbon brushes, the brush position should remain constant for all loads, without any sparking. Needless to say, the engine and dynamo are coupled direct and mounted on one combined bedplate.

The coupled plant is usually fixed on the starting platform, or on a "stringer" near by, in order that it may be under the eye of the engineer on watch. If on the starting platform, the foundation consists of stiff steel plating riveted to the web frames of the ship's bottom, or if on a "stringer" this is bolted or riveted to the steel side frames of

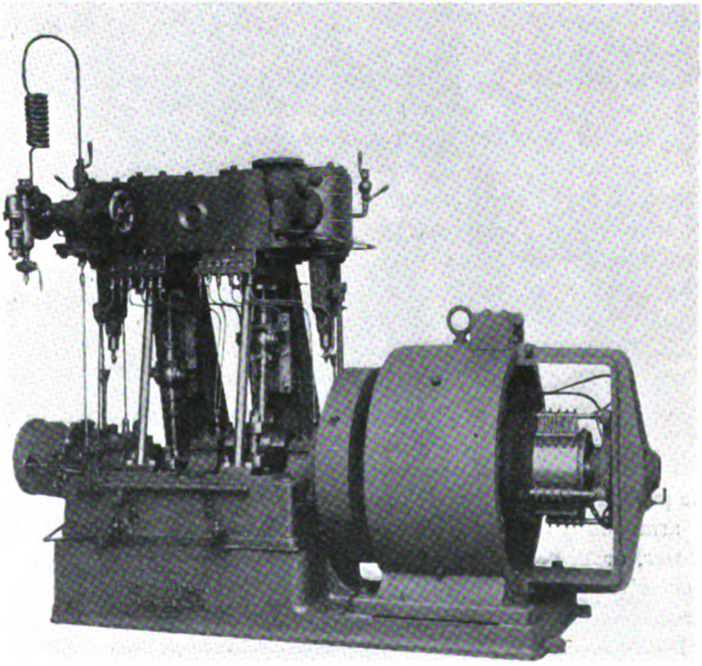


FIG. 3. SHIP-LIGHTING SET: COMPOUND OPEN TYPE ENGINE.

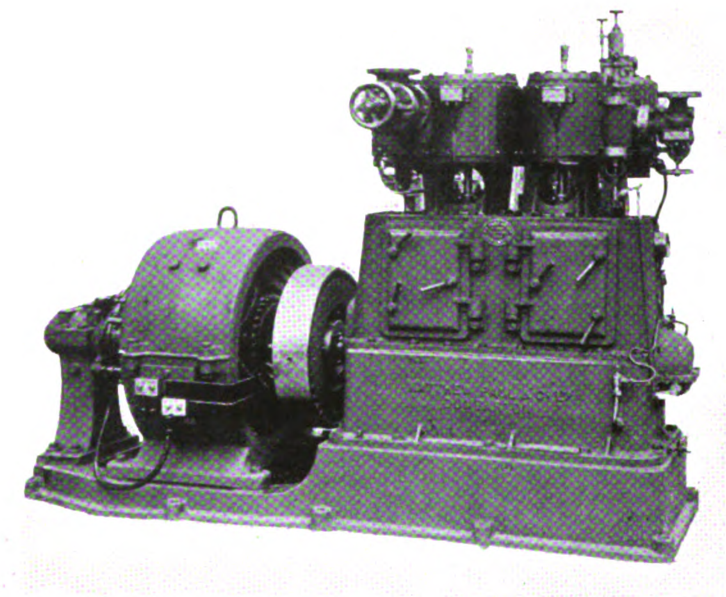


FIG. 4. SHIP-LIGHTING SET: COMPOUND ENCLOSED ENGINE.

the ship, the outer end being supported by stanchions.

A teak or pitch-pine framing 1½in. or 2in. thick is fitted on the foundation, and carefully levelled before the bedplate of the coupled set is bolted down. This assists smooth and silent running.

Steam pipes are connected to both the main and donkey boilers, the latter being used chiefly when the vessel is in port. The donkey boiler pressure may be from 60lb. to 100lb. per square inch, while the main boilers are usually from 160lb. to 180lb. pressure.

As the electric light engine has to develop its full power when running on the donkey boiler, it is usual to fit a reducing valve in the pipe from the main boilers. The engine is arranged to exhaust either to the condenser, or direct to the atmosphere, a two-way valve being fitted in the exhaust pipe for this purpose.

Both the engines and the dynamos for ship lighting should be thoroughly well designed and liberally proportioned to allow of their being run for very long periods without a stop. Cases have come under the writer's experience of plants having run continuously day and night for sixty days at a time.

Main Switchboard.

The main switchboard is usually of marble or polished and enamelled slate, fitted with a voltmeter, the necessary number of circuit switches, and double-pole fuses for same, and also with an ammeter, when projectors or arc lamps are fixed on board. The simpler the switchboard is, the better.

The main cables are run from the circuit switches of the main switchboard to double-pole fuse boxes fixed in convenient and accessible positions near that part of the ship which they serve.

Sub-mains are then run from these points to distributing double-pole fuse boxes, branch wires being run from the latter to feed not more than three or four lights. A diagrammatic sketch of this arrangement of wiring is given in Fig. 6, which shows everything clearly.

Main Cables and Branch Mains.

A short description of the class of cables usually employed and the method of fixing the same may now be given. Main and sub-main cables are insulated with pure and vulcanised rubber, taped and braided. They are preferably run in iron pipes, or they may be insulated as above with the addition of a lead covering, which is then taped and armoured with galvanised iron wire over all.

The branch wires from the distributing boxes to the lights, in engine room, boiler room, and tunnel, are usually armoured as above, while for the accommodation (state rooms, officers' and engineers' quarters, &c.), lead-covered wires are fixed by brass clips to the bulkheads or ceilings.

The main cables are usually led up the engine room bulkhead, thence through to the "'tween decks" at the nearest position to the various section boxes. If the cables are run in iron pipes in the "'tween decks" the pipes are fastened by clips to the underside of the deck beams.

Suitable draw-in boxes are fixed at intervals to facilitate the drawing-in of the cables, and for carrying out repairs at some future time. In some vessels iron pipes are unsuitable in the "'tween decks," owing to the nature of the cargo to be carried, such as timber or cotton; but when they *can* be employed, an excellent and lasting job can be made if the piping is erected and fixed in a careful manner, and suitable draw-in boxes of ample size are used where any bends or branches occur.

If lead-covered and armoured cables be used, they are fixed to bulkheads, &c., by brass or galvanised iron saddles, these being secured by ⅜in. Whitworth round-head screws.

In the "'tween decks" the cables have to pass through the deck beams, which are spaced approximately 2ft. apart; the cables are clipped up to the underside of the deck between the beams. Clips should not be spaced more than 1ft. apart.

Where the cables pass through watertight bulkheads, proper gunmetal stuffing boxes have to be fitted to comply with Board of Trade and Lloyds' requirements, and when the cables pass through a deck, suitable flanged metal tubes are used, making a thoroughly watertight joint between the tube

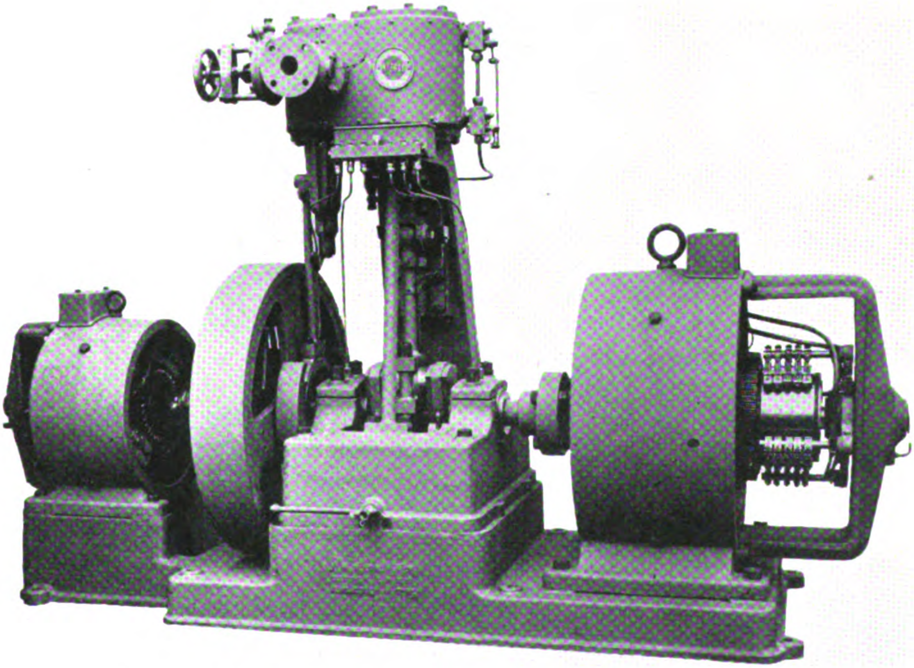
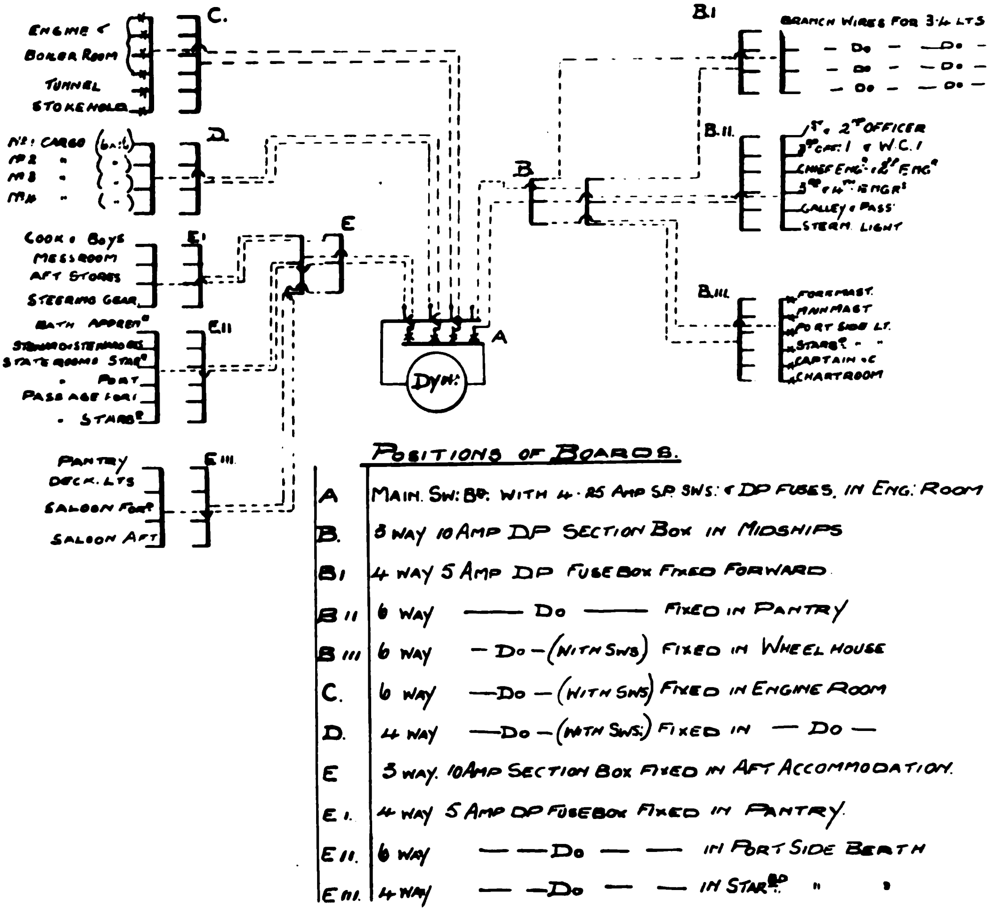


Fig. 5. Yacht-lighting Plant: Single-cylinder Open Type Engine with Automatic Cut-off Flywheel Governor, direct coupled to Main Dynamo, and having Booster at other end for Charging Battery.



POSITIONS OF BOARDS.

A	MAIN. SW: B^D: WITH 4 · 25 AMP S.P. SWS: & D.P. FUSES, IN ENG: ROOM
B.	8 WAY 10 AMP D.P. SECTION BOX IN MIDSHIPS
B I	4 WAY 5 AMP D.P. FUSE BOX FIXED FORWARD
B II	6 WAY —— Do —— FIXED IN PANTRY
B III	6 WAY — Do —(WITH SWS) FIXED IN WHEEL HOUSE
C.	6 WAY —Do —(WITH SWS) FIXED IN ENGINE ROOM
D.	4 WAY —Do —(WITH SWS:) FIXED IN — Do —
E	3 WAY. 10 AMP SECTION BOX FIXED IN AFT ACCOMMODATION.
E I.	4 WAY 5 AMP DP FUSEBOX FIXED IN PANTRY.
E II.	6 WAY ——Do — — IN PORT SIDE BERTH
E III.	4 WAY — —Do — — IN STAR^BD " "

FIG. 6. DIAGRAM OF SHIP-LIGHTING CIRCUITS.

and the deck. After the cables have been drawn through, the tops of the tubes are sealed up with waterproof compound to prevent any water passing through to the space below.

The wires for the mast-head light are usually run up the mast in iron pipe, and if the lantern is permanently fixed the iron pipe is run directly into it.

If, however, the lantern is portable, the iron pipe should terminate in a "gooseneck" bend with a watertight socket connection screwed on to it.

The wires for port and starboard lights are sometimes run direct into a permanent lantern, or terminate in watertight socket connections fixed in the nearest convenient position. Flexible cables are then run from these sockets to the lanterns.

Fittings, Switches, and Lamps.

The fittings for the lamps in saloons and state rooms vary very considerably according to the class of vessel. In the officers' quarters, brass fittings, either polished or bronzed, with frosted lamps or globes, are usually employed.

In engine rooms, crews' quarters, &c., the fittings are also of brass, substantial in design, with well glasses, strongly guarded, to withstand rough usage.

Where lamps are fitted in the "'tween decks" they should be in very strong cast-iron fittings, with a hinged solid cover, which can be closed over the glass entirely, and fastened by wing nuts, when the space is to be filled with cargo, and the lights not required.

Engine rooms and boiler rooms should have plenty of portable lamps, current being conveyed to them by flexible armoured wire, from wall sockets fixed in convenient positions on the bulkheads. The hand-lamp fittings should have large hooks at the top, so that they may be hung up in any convenient position.

Distributing Fuse Boxes.

Distributing fuse boxes in exposed positions are fitted in cast-iron cases, the fuses being of the clip type, easily replaceable. In the accommodation, teak fuse boxes with glass fronts are employed.

Branch switches are usually of the tumbler type, every light in the living spaces having its separate switch.

No switches or fuses should be fitted in cargo spaces or coal bunkers, but the lights in these parts should be controlled in groups of three or four, the switches and fuses being arranged in some near and convenient position. Engine and boiler room lights are preferably controlled in groups from a sub-switchboard fixed near the main switchboard.

The switches controlling the navigation lights—foremast, mainmast, port and starboard side lights, and stern light—should be fixed in the wheel house, under the control of the officer on watch.

In some vessels a tell-tale indicator is fitted in the wheel-house, so that in the event of a lamp going out—through a filament giving way or other cause—a tell-tale lamp is lighted and a bell rung to give warning of the fact. The lamps throughout the ship are usually of 16c.p., except in the binnacles and telegraphs, where 8c.p. lamps are used. Navigation lights are fitted with 32c.p. lamps, with twin filaments enclosed in one bulb, as it is unlikely that both filaments will give out simultaneously. In the event of one filament breaking the remaining one gives sufficient light to meet the Board of Trade requirements.

A suitable tell-tale indicator will give warning when only one of the two filaments has given out. The lamp can be replaced at the first convenient opportunity.

Many hundreds of steamships of various classes have been lighted on systems and methods similar to those just described, and time has proved their worth and excellence.

YACHT INSTALLATIONS.

The electrical equipments on board steam yachts vary a good deal, depending upon the tonnage, the internal fittings generally, and, of course, the amount of money the owner is willing to spend upon this portion of the work. It is needless to add that a yacht installation is not complete without a storage battery, so that the lights can be run (at night, especially when the yacht is in port) direct from the cells, dispensing with the running of the engine and dynamo so that absolute quietness reigns, adding to the owner's or guests' comfort when on board. On an installation of, say, 120 lights, the plant usually consists of an engine and dynamo, storage battery, main switchboard, with the necessary main and circuit switches, instruments, cell switches, cell charging and discharging switches, and automatic cut-in and cut-out switch.

Assume the voltage to be 100, which is now generally adopted for installations of this class, the dynamo being shunt-wound, giving an output of, say, 60amp. at 100 volts when running direct to the lights, or 60amp. at 148 volts when charging the cells, the board is arranged for: (1) running direct to the lights from the dynamo; (2) charging the cells only; (3) running the lights from the battery only; (4) dynamo and cells in parallel to the lighting if required, as per diagram of connections shown in Fig. 7.

Storage Batteries.

The cells are usually fitted in strong lead-lined teak boxes, the lids being fastened to the boxes by strong brass wing nuts, and a

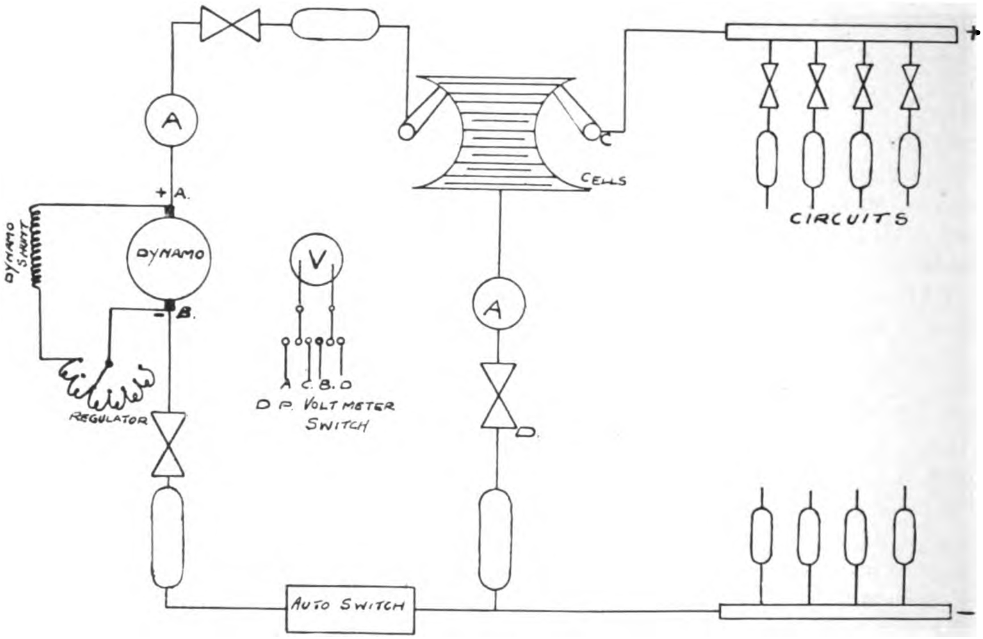


FIG. 7. DIAGRAM OF YACHT-LIGHTING SYSTEM WITH BATTERY.

strong rubber ring inserted between the lid and the box to prevent leakage of the electrolyte. The lid should also have inspection holes of 2in. to 3in. diameter (according to the size of the cells), fitted with tapered plugs, easily removable, so that inspection can be made readily while charging is taking place, or for the purpose of adding water or fresh electrolyte without removing the lid.

Owing to the limited space on board the majority of yachts it is not possible to have a separate battery room, as on land installations, and as it is advisable to have the cells as near the main switchboard as possible to keep the cost of cables down, they are usually fixed either in the thrust recess or in the tunnel; sometimes in both, according to the space available, the regulating cells being nearest the main switchboard.

The stands for receiving the cells are generally constructed of knee-shaped angle iron bars bolted or riveted to the side frames and carried down to the web frames at the ship's bottom, trays being arranged in tiers and constructed of teak or pitchpine, the whole being lead-lined to take any acid which may leak out of a defective or damaged box. Between the cells and the lead-lined trays teak paraffined strips are placed to keep down surface leakage; division strips of teak are placed between each cell, and each tier of cells well stayed and bound together by wood battens, to prevent shifting of the cells at sea. All iron and woodwork in the neighbourhood of the battery should be treated with anti-sulphuric paint.

Wiring.

The wiring for the installation is carried out on similar lines to that of ordinary merchant steamers with the exception that in the owner's and guests' quarters and living accommodation surface wiring is not very suitable from an artistic point of view in these positions. Vulcanized rubber-insulated cables and wires of the best quality are usually run in wood casing fixed to the undersides of the deck behind the panelling, or where it is not possible to run casings the wires are placed behind the mouldings and framing, all coverings being fixed with wood screws.

It may be here mentioned that designers and builders do not give sufficient consideration to this all-important matter from an electrical point of view, as it could be easily arranged to have receptacles provided both fore and aft and athwartships to take the necessary cables and wires without interfering with or spoiling the design of the panelled ceilings.

The above applies to the sub-mains and branch wires only, as in practice it is not possible to run the main cables on deck in this manner owing to the insufficient space available, but a very satisfactory method is to keep all main cables on the lower deck, enclosing the cables in galvanized iron pipes, suitable draw-in boxes being provided at each point where the mains rise to the respective distribution boards.

Distribution Fuse Boxes.

As the panelling and framing in the principal living parts is generally of very high-class design and finish, a very neat job can be made by having recesses built in the panelling to receive the boxes, the front of the box forming part of the design of the panel.

Switches.

Switches are usually of the sunk type mounted in brass boxes, the panels of framing being recessed to take the switch box, so the plates only project from the surface.

Fittings.

In the principal rooms the fittings are generally of very choice design, finished

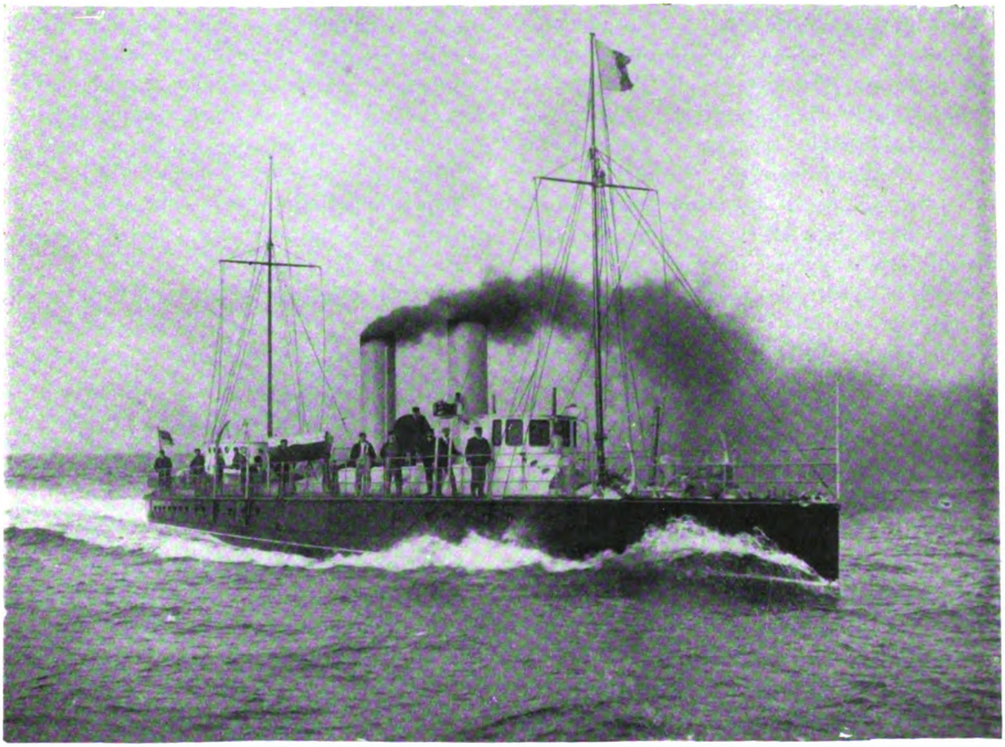


Fig. 8. Mr. C. W. Vanderbilt's S.Y. "Tarantula."

This was the first Steam Turbine Yacht built. It is equipped with a "Castle" Steam-electric Generator and complete Plant of Accumulators and Switchboard. In addition to the permanent lighting, the equipment includes Coaling Clusters, Connections for Festoon Lighting, Portable Table Lamps and Hand Lamps for the examination of machinery, &c.

in electro-silver plate, oxidised silver or gilt, to match and harmonise with the surrounding fittings. Table lamps are very freely distributed throughout and are fed from wall sockets recessed into the panels similar to the switches. At regattas it is no unusual sight to see yachts festooned from stem to stern with coloured electric lamps, which are fed from socket connections fixed at different positions on deck, a special circuit being arranged from the main switchboard to enable this to be done when required.

On some of the larger yacht installations a booster is coupled direct to the same shaft as the main dynamo (see Fig. 5), the dynamo, or dynamos, if more than one, being compound wound, which enables the plant to be run direct on the lights and to charge the cells at the same time through the booster.

Typical Installation.

Perhaps a short description of the electrical equipment of a millionaire's yacht fitted out last year by J. H. Holmes & Company may be interesting. The plant consisted of three compound forced-lubrication engines, having cylinders 6½in. and 11in. diameter by 6in. stroke, each capable of giving 48b.h.p. at a steam pressure of 180lb. per sq. in. when running at a speed of 450r.p.m. Each of the above engines was coupled direct to a compound-wound dynamo with an output of 110 volts 280amp. Two of the dynamos had a booster coupled direct on the same shaft, Fig. 5, giving an output of 56 volts 110amp., the approximate weight of each set being 85cwt., so that in ordinary working conditions one of the generators with its booster could be used during the day for lighting the engine room and other parts of the ship where light was required, and at the same time the battery charging could take place through the booster, and as two of the generators were fitted with boosters, one set could be run alternatively every other day, or in the event of a breakdown the other set would be available. If steam were kept up while waiting for sailing orders, the coupled set without the booster could be run direct on to the lights if the engineer wished to keep the battery in reserve.

The main switchboard occupied a space of 9ft. by 5ft. 9in., and was fitted with all the necessary instruments, main switches, and protective devices usual for a plant of this description.

It was so arranged that the plant could be run in the following sequence, according to the requirements of the occasion (Fig. 9):—

(1) Either generator running direct (as a compound machine) for lighting and power purposes.

(2) Either generator running as above and charging the cells through the booster at the same time.

(3) Either two or three generators running in parallel when required.

(4) Discharging from the battery only.

The circuit switches consisted of sixteen 50amp. change-over switches for the lighting circuits, so that these could be run from the battery or dynamos as required. Six 50amp. single-pole switches were also fitted for the power circuits, so that these could be fed from the generators only.

The storage battery consisted of sixty cells capable of giving out 96amp. for seven hours.

At first sight it might appear that in practice it would never be required to run the generators in parallel, but when the extent of the electrical installation is taken into consideration, this does not seem so improbable, as the installation consisted of:

(*a*) 400 16c.p. lights distributed throughout the yacht.

(*b*) 150 plug connections for reading lamps or table fans.

(*c*) One 20in. projector fitted on the bridge.

(*d*) Provision made for decoration purposes at regattas for lighting 1500 lamps of 5c.p., 8c.p., and 16c.p.

(*e*) Supplying current for twenty-four motors totally approximating 28b.h.p., besides a number of plug connections fitted in the galleys and pantries for grills, coffee heaters, and other cooking apparatus.

The ventilation of the living rooms was

carried out by electric motors, twenty in number, coupled direct to small centrifugal fans, the power of the motors varying from $\frac{1}{2}$h.p. to 1h.p. each. Particular attention was given to the positions of the motors and fans to prevent any noise being heard in the rooms.

Two motors of $3\frac{1}{2}$h.p. each coupled direct to centrifugal fans were fitted in the "fiddley" for the ventilation of the stokeholds and engine room.

A very complete laundry outfit was arranged on board, the machinery being driven by electric motors.

Other electrical apparatus fitted on board consisted of two patent log-recorders, one recorder being fitted in the engine room and the other in the chart house, registering in $\frac{1}{10}$ths of a knot and knots. There was also an automatic apparatus for controlling electrically the vessel's steam whistle; these special switches being fixed on the bridge, one at either end for operating the steam whistle as desired, and one in the centre which could be operated at will, or, if placed in a certain position, the whistle could be operated automatically to blow at given intervals according to the setting of a special controlling apparatus fixed in the chart room. Wireless telegraph apparatus are also fitted on board in a special house built on the boat deck, the direct-current motor coupled to the alternator being fixed in the engine room.

As previously mentioned, provision was made for lighting 1500 lamps for decoration purposes. Twenty special circuits were run for this purpose from distributing fuse boxes, with controlling switches fixed in the engine house, to special water-tight sockets fixed in convenient positions, each socket having a reference letter corresponding to the reference letter on the plug attached to the length of decoration belting. The decoration belting of twenty separate portions, averaging about 150ft. in length, consisted of four separate insulated cables under one covering, the lamps being spaced 2ft. apart and coloured red, blue, and white, the lamp-holders forming part of the cable and made absolutely water-tight. The lamps were of the screw pattern with rubber

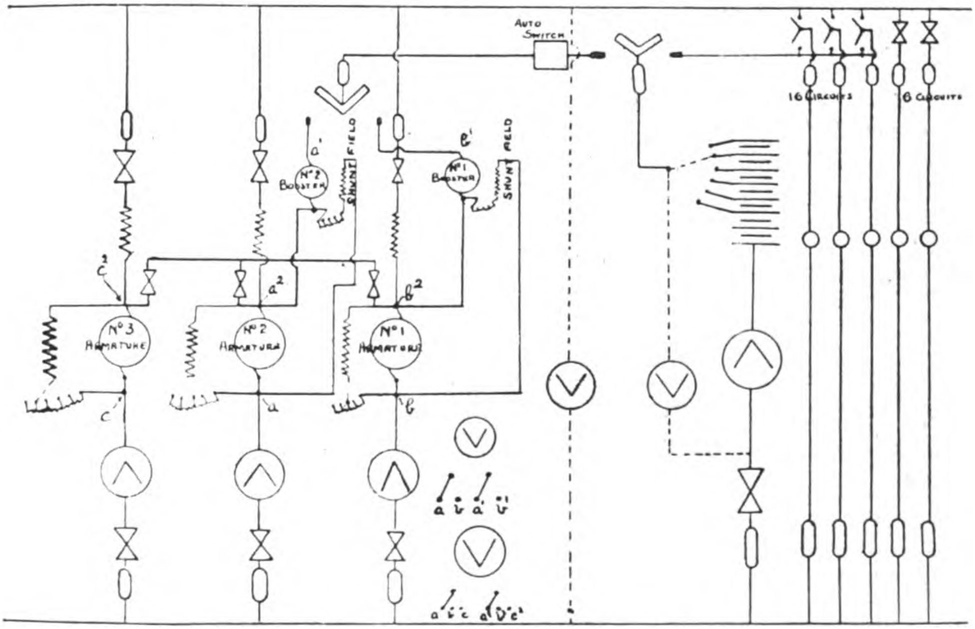
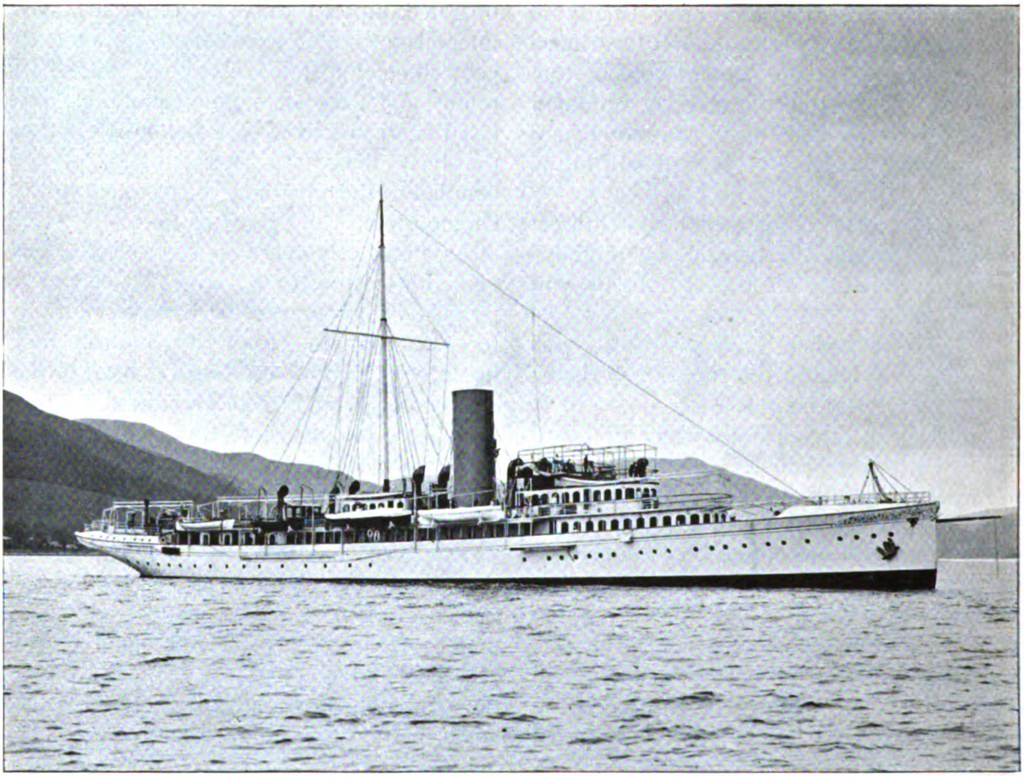


Fig. 9. Diagram of Connections of Yacht Installation.



S.Y. "LYSISTRATA" (OWNER, JAMES GORDON BENNETT, Esq.).

The electric plant on this vessel consists of two steam generators supplying 450 16c.p. lamps, three projectors (two 20in. and one 24in.), a number of ventilating fans for state rooms, and two electrically-driven Cyclone blowers, each moving 2400 cubic feet of air per minute. The yacht is also fitted with telephone installation and two complete batteries of accumulators.

gaskets fitted to the collar, making a very satisfactory job. The white, red, and blue lights were controlled separately from the engine room.

The belting when in position was so arranged that a complete outline of the yacht could be viewed illuminated at night from stem to stern on the water-line, load-line, main deck, upper deck, bridge deck, up both masts, each side of funnel, and around the top of same, as well as a complete stream of light up the fore stay to the top fore mast, and from top fore mast to main mast and down the after stay. When illuminated at night this had a very nice effect.

Some sixty or seventy yachts have been fitted up with electrical installations on the foregoing lines—not so elaborate in all cases—which have given great satisfaction to the designers, builders, and owners. Among this number are included yachts owned by many Royal personages, American millionaires, &c., &c.

NOTEWORTHY PLANT AND APPLIANCES AS USED ON SHIPS AND IN SHIPYARDS.

Tubular Construction as Applied to Shipbuilding.

One of the most noteworthy developments in modern shipbuilding is the increased use of tubular steel construction. For steam, feed, and other high-pressure pipes, where formerly copper was almost exclusively used, iron and steel pipes are now the general practice.

Prior to the building of the *Campania* and *Lucania*, copper steam pipes were exclusively used, but the high steam pressures and consequent high temperatures and large diameters required for these boats precluded the use of copper, and iron pipes were successfully adopted. Since that date the use of iron and steel pipes on board ship has gradually extended, until the advantages of their use have become so generally recognised that not only are they specified for all new work, but it is significant that, in numerous cases lately, copper steam pipes have been replaced by iron and steel. For instance, Messrs. Stewarts & Lloyds, Ltd., the well-known tube makers, make no secret of the fact that they have made this alteration in no less than five large steamers during the last three months.

The Board of Trade officials some years ago made a series of destructive tests in Stewarts & Lloyds' Works of iron steam pipes with flanges welded on. For this purpose, short lengths of pipe with flanges on each end were cut longitudinally into four sections, and demolished under steam hammers. Under these tests the flanged pipes were bent and finally broken, but the continuity of the weld remained intact; since these tests the Board of Trade have accepted the welded flanged pipes of this Company's manufacture for all work under their survey.

Tubular construction, as apart from pipe work, in shipbuilding is particularly applicable to such details as deck stanchions, cargo derricks, boat davits, masts, and to all other members subject to considerable strain and to which the tubular form may be conveniently applied. This is readily appreciated when one considers the relative strength of the tubular form for long struts, compared with other sections, as shown below:

A steel tube 7¼in. external diameter by ⅛in. thick, weighing 10lb. per foot, is equal to:

A cast-iron pipe 5in. external diameter by 1in. thick, weighing about 40lb. per foot.

A steel angle 7½in. by 7½in. by ½in., weighing about 25lb. per foot.

Three tee bars 6in. by 4in. by ½in., weighing about 48lb. per foot.

An "H" beam 8in. by 6in. by ½in., weighing about 35lb. per foot.

A channel 15in. by 4in. by ⅜in., weighing about 51lb. per foot.

A solid steel bar 4½in. diameter, weighing about 54lb. per foot.

Tubular steel deck stanchions are now regularly employed for Admiralty work; while modern high-speed mail boats, including the most recent record-breakers, the *Mauretania* and the *Lusitania*, are fitted with tubular steel derricks and davits, the weight saved in these latter fittings alone amounting to about twenty-five tons, which is of the highest importance for such fixtures high above the water line.

Turning to the boiler room, the use of

steel tubes, while it has always been a large item in the construction of the Scotch boiler, with its battery of return tubes, forced draught heater tubes, and feed and steam pipes, is now more than ever in evidence, due to the adoption of water-tube boilers for marine use, particularly those of the Babcock, Yarrow, and other accepted types. It is said that Stewarts & Lloyds, Ltd., supplied no less than 55,000 boiler tubes for the *Lusitania* and *Mauretania* alone, not to mention the large number of steam, feed, water, electric conduit, and structural tubes required for these boats.

Before a committee of enquiry one of our most noted marine engineers recently expressed the opinion that copper tubes fitted with brazing metal flanges were an incessant source of trouble on board ship, their dimensions being cut down to the minimum to save weight and expense. Unless made of excessive thickness, these brazing metal flanges twisted and dragged out of shape, causing leaky joints and requiring re-facing before the joint could be re-made. Copper tubes have, of course, the peculiar advantage that they can be readily bent and adjusted to awkward positions, but the relative cheapness and reliability of steel pipes far outweigh this factor, and are being proved to-day as altogether superior to the older expensive method.

◆

Electric Shipyard Cranes.

Two noteworthy examples of modern electric shipyard cranes are illustrated in Figs. 1 and 2. They are both of the Leeds Engineering and Hydraulic Company's construction, the former being a three-ton self-contained pedestal crane as used for stacking ship plates. The crane has a rake of 40ft. and turns a complete circle. Two motors comprise the electric power equipment, and these provide all motions—hoisting, racking, and slewing.

The second illustration is also of a three-ton crane capable of being turned through a complete circle by hand, and having a rake of 30ft. The mast is mounted on ball-bearings to permit of ease in turning by hand. One motor of the totally enclosed type provides the power for the hoisting and racking motions. The motor is carried on the back jib, the balance weight being utilised as a base for the motor. The lift of the crane is 16ft. clear.

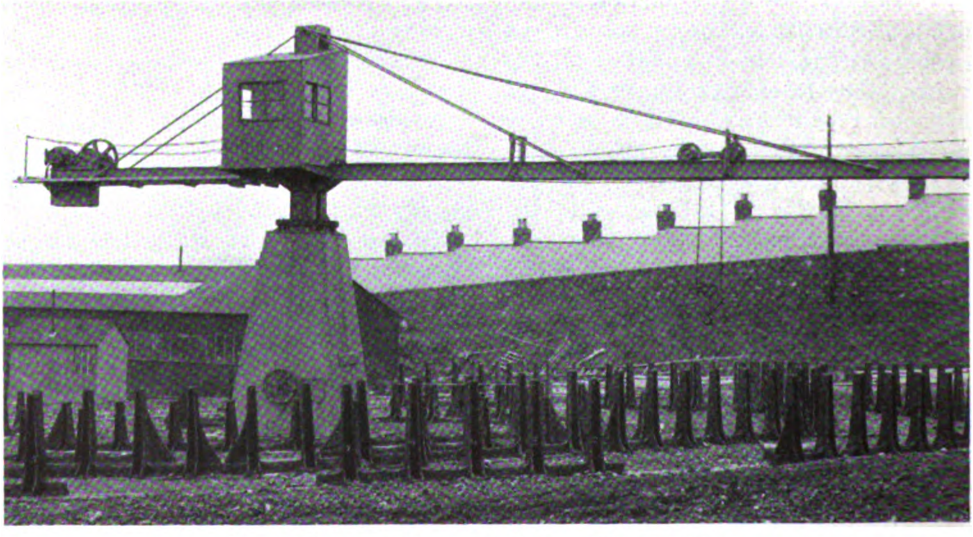


FIG. 1. THREE-TON TWO-MOTOR ELECTRIC PEDESTAL CRANE.

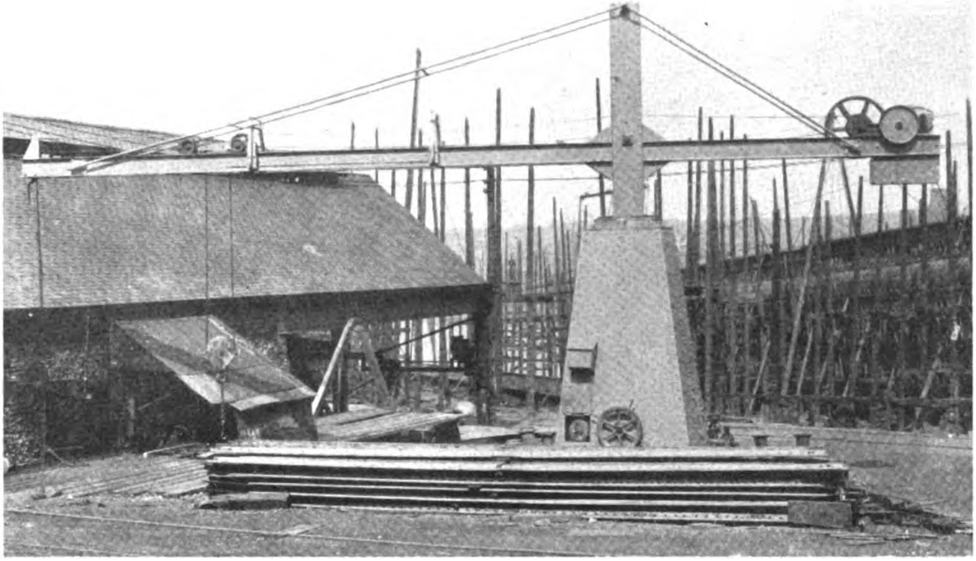


FIG. 2. THREE-TON SINGLE-MOTOR PEDESTAL CRANE.

Electric Motors.

Electrical engineering is nothing if not progressive; and in no branch of industry, perhaps, has this been exemplified better than in the shipbuilding industry. The adaptiveness of electrical driving to all kinds of work has ever been the strongest point in its favour. Electrically power is transmitted from the generating plant to the motors with the minimum of waste; electrically the motive power is applied to the driven machine in the most convenient and effective manner; and electrically the power of the generator may momentarily be concentrated on one or two motors to the extent of—in the case of continuous-current and three-phase motors at any rate—two or three times their rated capacity. But it is unnecessary to enumerate the advantages of electric power transmission at the present day, for they are already well appreciated, and it has become merely the question of capital outlay which prevents its universal adoption.

The work of a shipyard being of a heavy nature, it is of importance that the motors to be used for driving the machine tools should be not only of strong mechanical construction, but also designed electrically so as to be capable of carrying very heavy momentary overloads efficiently and without injury. The illustrations Figs. 1 and 3 are of motors made by T. W. Broadbent, Ltd. The "M" type continuous-current motor, Fig. 1, may be regarded as of typically strong construction. These machines are made protected, ventilated, or totally enclosed as required. The magnet cores and frames are of cast steel, and the poles are of laminated iron. It will be noticed from the illustration that the end shields of the motor are of a particularly open construction, affording easy access to the commutator and brush gear. The makers, who have had many years' experience of the manufacture of these motors, have given special attention to the questions of efficiency and commutation, and it is their claim that the "M" type motor is absolutely sparkless under all conditions of load up to 25 per cent. overload. For controlling these motors, Messrs. Broadbent have introduced a double-pole quick-break starting switch, known as the "H" type motor starter (Fig. 2). It is provided with a no-volt and overload automatic release and two fuses.

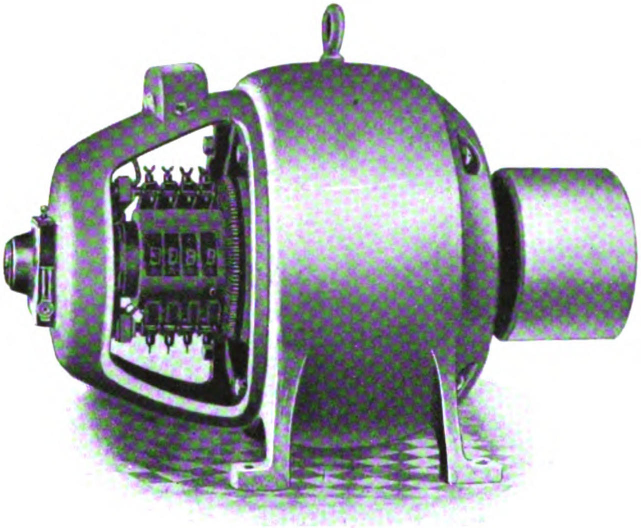


FIG. 1. BROADBENT TYPE "M" DIRECT-CURRENT MOTOR.

The other motor illustrated (Fig. 3) is the "N" type three-phase motor of the squirrel-cage class, and, as is becoming usual nowadays, the makers recommend the squirrel-cage motor for almost every class of work—for the reason that this class of motor is of higher efficiency and power-factor than the slip-ring motor, and it is, moreover, far more reliable in operation. The "N" type three-phase motor is of strong mechanical design, all the parts being of liberal proportions. The stator has partially closed slots, this form of slot having been found to give the best results as regards efficiency and power factor. The coils are former wound and are partially insulated before assembly. In accordance with best modern practice, they are also separately treated with insulating varnish and "stoved" at a high temperature. This method ensures a thoroughly safe and permanently high degree of insulation, and is common practice nowadays with the leading makers—the old-fashioned hand winding being rarely used on account of its greater liability to breakdown of the insulation. The rotor cores are of the "iron-clad" or pierced type. The rotor bars are lightly insulated—a practice which is not yet as common as it should be; and special care is taken to ensure perfect low-resistance short-circuiting connections at the ends.

Messrs. Broadbent's specification of these motors indicates that the power factors and efficiencies test out very high, figures of the power factors and efficiencies of a few sizes being given in the table below.

For operating these motors, a starter of special design has been evolved. It is of triple-pole construction, the switch completely breaking the circuit on each of the phases, so that a separate main switch is unnecessary. The starter was originally of the change-over type; but in order to be able to fit a no-voltage release to the starter, this type of switch has been discarded in favour of the flat contact type, with a switch brush sliding over the contacts. To meet the more exacting requirements of the present day, these starters are now made of the enclosed pattern. The starter is of

N TYPE THREE-PHASE MOTORS.

WOUND FOR 100, 200, AND 400 VOLTS.

PERIODICITY—50 PERIODS OR AS OTHERWISE ORDERED.

Catalogue Size.	Output.		Per cent. Efficiency.		Per cent. Power Factor.		Temp. Rise.
	b.h.p.	r.p.m.	½-load.	Full load.	½-load.	Full load.	deg. F.
N ⅔	3	2780	62	79	64	83	81
N2¼	5	1400	68	83	66.5	84.5	78
N3½	7	1410	71	84.5	69	85	77
N 6	10	950	74	86	71	86.5	74
N10	15	955	76	87	72.5	87	74
N16	20	960	77	87.5	74	88	73
N21	25	725	79	88.5	75.5	89	72
N34	30	725	80	89	77	90	71
N41	40	730	81	90	78.5	91	69
N55	50	730	81.5	91	80	92	69

the auto-transformer type. This method is much more economical than that of starting merely through ohmic resistances; the current at starting is less (with a loose pulley on the driven shaft, the starting current is only about two-thirds the full load running current); and the current taken is practically wattless, owing to the phase lag of the current with this type of starter. This motor starter is known as the "T. P." type, and is made in four standard sizes, each of which may be wound for 100, 200, or 400 volts, as required.

Single-phase motors, although not possessing the practically unlimited overload capacity of continuous or three-phase current motors, are, nevertheless, very satisfactory machines, provided motors of sufficient power for the work required are installed. The "N" type single-phase motors made by T. W. Broadbent, Ltd., are guaranteed to take a load 25 per cent. greater than their rated output without being pulled "out of step." They are very effective in starting up, and the makers have recently introduced an improvement in their design, by which they are able to start with a current not exceeding the full load running current. This marks a distinct advance in single-phase motor practice, as the starting current usually specified for single-phase motors has hitherto been one-and-a-quarter times the full load current. The starting current in these motors is, it may be remarked, almost wattless, even at this low figure. The efficiencies and power factors are comparatively high, being only a few per cent. less than those obtained with the three-phase motors. The "P" type starters, for use with the "N" type single-phase motors, are enclosed; they are of double-pole construction, a separate main switch being thus unnecessary when these starters are used. These single-phase starters, being very simple in operation, may be trusted to the care of any inexperienced person without risk of injury.

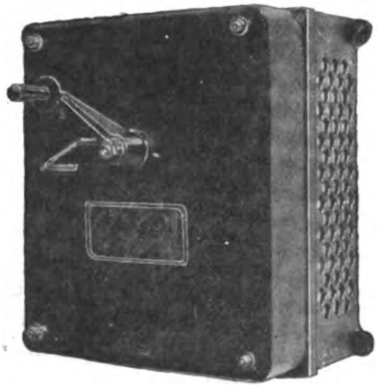


FIG. 2.

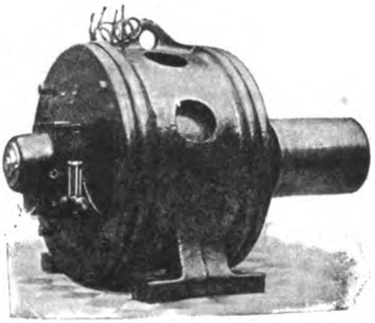


FIG. 3.

With regard to the probable cost of electric driving it may be mentioned that with a small generator—either continuous or three-phase current—of, say, 100kw. capacity, driven by a good high-speed condensing engine, the actual cost of producing electrical energy, after allowing for interest on capital outlay and for depreciation of the plant, works out at about ½d. per Board of Trade unit. This would be the cost where coal costs about 13s. per ton, but in districts where coal can be obtained more cheaply the cost would be rather less.

◆

Electric Shipbuilding Berth.

The accompanying illustration, Fig. 1, strikingly demonstrates the system of crane equipment for slips or berths of shipbuilding yards which has lately been introduced at a new shipbuilding yard at Dalmuir, near Glasgow. The constructional work for the berth was supplied by Sir Wm. Arrol & Co.,

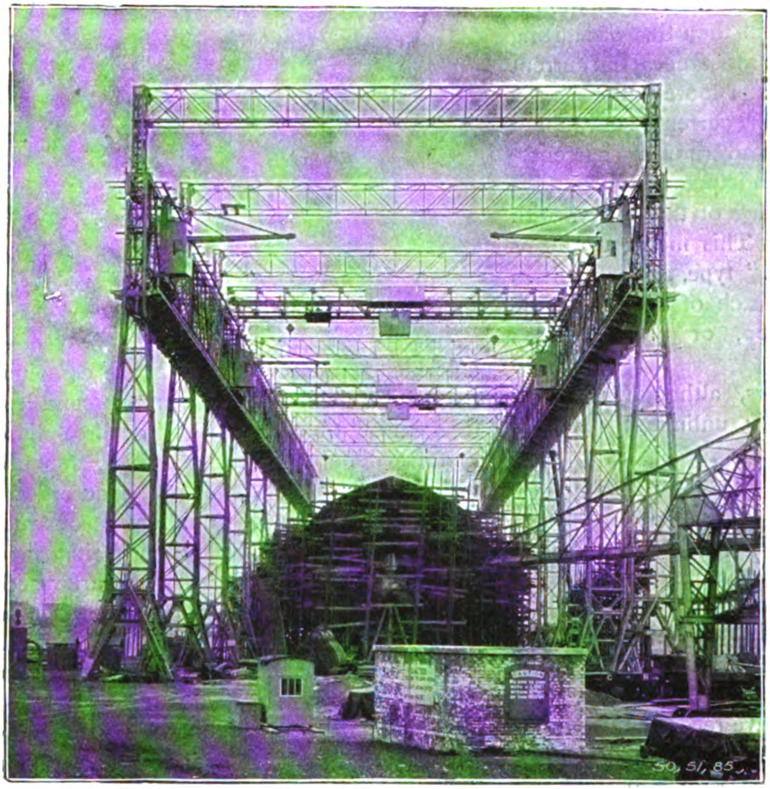
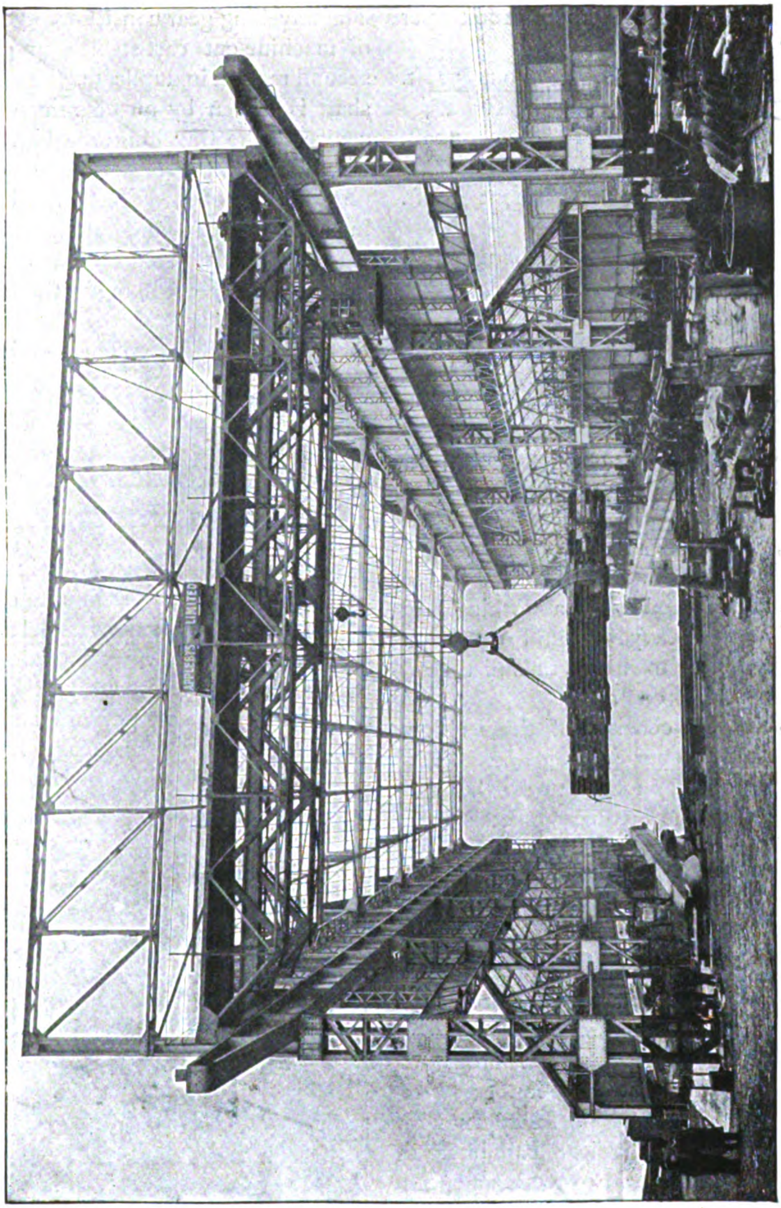


FIG. 1. APPLEBY ELECTRIC CRANES ON SHIPBUILDING BERTH.

Ltd., and the cranes by Appleby's, Ltd., from their Glasgow works. The crane installation consists of the combination of overhead travelling cranes with side walking cranes, by means of which shipbuilding material can be most quickly and easily manipulated, the cranes being used either separately for different squads of men, or in combination for dealing with specially heavy loads. As will be seen from the illustration, the equipment consists of a number of lattice columns supporting gantry girders upon which the overhead cranes travel. The columns are rigidly held together by means of light cross girders, under which run the travellers commanding the whole area of the slips. The columns also carry rails or channels on which two or other number of ordinary walking cranes can run. These cranes are arranged at either side of the structure, and are so fitted that their jibs can be swung round over a vessel under construction or to the side thereof. This arrangement has been found to satisfy all the requirements which experience has suggested, and it enables the material to be handled with the minimum delay, whereby the fitters or platers are regularly supplied with such material as and when required. The number of cranes which are employed in the Dalmuir installation also enables an equivalent number of squads of fitters or platers to be continuously and efficiently employed, each crane being able to traverse the whole distance of the berth with its load. Furthermore, two or more cranes may be brought to bear upon an exceptional load.

The lattice girders which connect together at the top of the vertical members, thus preserving the gauge of the crane gantry, may, if desired, be replaced by roof principals at a somewhat increased cost, and they can be roofed in with glass or other material, so that complete protection is afforded in all weathers during construction, and work can be proceeded with uninterruptedly. In the particular equipment described the overhead travellers are electrically driven, and are proportioned for a working load of 15 tons, the span being 108ft., and the total length of the gantry 750ft. The walking cranes are also electrically driven, and are four in number, two on



Fifty-ton Electric Shipyard Crane.

each side of the gantry, each commanding an area of 30ft. radius. The overhead travelling cranes have a vertical lifting range of 140ft., and three motions of lifting, travelling, and traversing, each operated by separate motors arranged to run on a 440-volt circuit. These motors are series wound, the lifting motor giving 50 brake horse power, running at 500r.p.m., the travelling motor 30 brake horse power, running at 500r.p.m., and the traversing motor 10 brake horse power, running at about 600r.p.m. The speeds attainable are as follow:—

Lifting, with full load, about 40ft. per minute.

Lifting, with no load, about 100ft. per minute.

Travelling, with full load, about 500ft. per minute.

Travelling, with no load, about 750ft. per minute.

Traversing, with full load, about 220ft. per minute.

Traversing, with no load, about 350ft. per minute.

◆

50-Ton Electric Overhead Travelling Crane.

The illustration on the preceding page shows one of three 50-ton electric overhead travelling cranes recently erected by Messrs. Appleby's, Ltd., for a new shipbuilding yard on the Clyde at Scotstoun. These cranes are constructed to lift a working load of 50 tons on the heavy hoist and 10 tons on the auxiliary hoist; to run on rails distanced 93ft. from centre to centre.

The lifting gear consists of three reductions of cast-steel spur gearing and a cast-iron barrel grooved in the lathe right-hand and left-hand. The auxiliary hoist is built independently of the main crab; it is self-contained and slung from one of the traverse wheel axles of the main crab and is driven through a double reduction gear of machine-cut steel spur wheels. The brake consists of a plain drum on the motor spindle gripped by means of a leather-lined steel brake band with weighted lever, released automatically by means of a solenoid connected in series with the lifting motor. In addition to this an automatic mechanical load brake is provided. This device also acts as a speed regulator; it is totally enclosed and always flooded in oil.

This brake is alone sufficient to sustain the full load, and the solenoid serves the purpose of an additional safeguard and brings the motor quickly to rest. The traversing gear consists of two reductions of machine-cut steel spur gearing. The travelling wheels are of cast steel with machined treads. The travelling gear consists of two reductions of machine-cut cast-steel spur gearing, the second motion in duplicate. The longitudinal shaft is driven by an electric motor at the centre. The travelling wheels are cast steel with machined treads, four in number, two on each side of the crane. All bearings are in halves with caps and gun-metal bushes. A platform is provided on each side of the crane running the whole length of the girders. The main girders are of the lattice type; they are further stiffened sideways by auxiliary or wind girders.

◆

Siemens Electric Revolution Indicator.

This apparatus is used for indicating the speed in revolutions per minute of an engine or other shaft at positions situated at a distance from the shaft. It is claimed to offer many advantages over all other types designed for the same purpose, and embodies several features which make it eminently suitable for indicating on the bridge of a

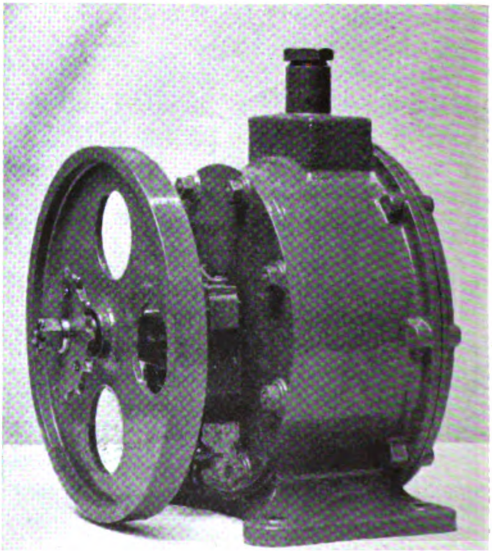


Fig. 1. Transmitter of Electric Revolution Indicator.

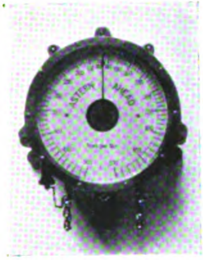


FIG. 2. RECEIVER OF ELECTRIC REVOLUTION INDICATOR.

vessel the speed at which the engines are running.

The method of transmission is by alternating current, supplied by a special form of generator, driven by chain gearing from the engine shaft, the indicators or receivers being voltmeters constructed on the well-known Ferraris principle.

The transmitter is constructed so that the voltage generated is exactly proportional to its speed, a result obtained by employing a fixed armature and revolving a magnetic field composed of permanent steel magnets. This method does away with the necessity of slip-rings and contact-brushes, which are liable to introduce errors due to wear taking place, with a consequent alteration of the points of contact, and also to variation of the resistance of the contact surfaces, causing a difference of voltage.

The Ferraris voltmeter, which forms the receiver or indicator, is the most accurate form of alternating-current voltmeter, and has the additional advantage of having a scale which extends over about 280 degrees, enabling the divisions to be large and open. The turning force of this type of instrument is also very great, by reason of which the pivots and other moving parts can be of substantial construction.

The transmitter, Fig. 1, is of water-tight construction, with very efficient lubrication to the revolving spindle.

For turbine-driven shafts, where the turning movement is uniform during a revolution, the chain drive is direct from the engine shaft, but for reciprocating engines the drive takes place through a regulator to ensure the speed of the transmitter keeping regular during a revolution. A flywheel is added to assist this. The regulator is a form of spring coupling arranged as a countershaft which is driven by a chain from the engine shaft, and to which the transmitter is connected by a chain drive. The receiver or indicator, Fig. 2, is contained in a water-tight case provided with lugs for fixing to a bulkhead or other support. Arrangements for illumination are provided when required.

Siemens Electric Helm Indicator.

This apparatus, which indicates on dial instruments on the bridge, or in other remote positions on the vessel where required, the angle of the rudder, consists of a transmitter situated near the rudder stock, and connected to it by means of a pulley and special driving gear, and of any number of indicators or receivers placed where required and connected to the transmitter by a five-cored cable.

The transmitter, Fig. 1, is a form of switch or contact maker, which sends current to a group of magnets in the receivers, and causes their armatures to revolve and move the pointers in such a manner that they take up positions corresponding with that of the rudder. The driving gear by means of which the transmitter is connected to the rudder consists of a grooved pulley clamped on to the rudder stock, and to which are fastened flexible steel wire ropes connected by special spiral spring couplings to lengths

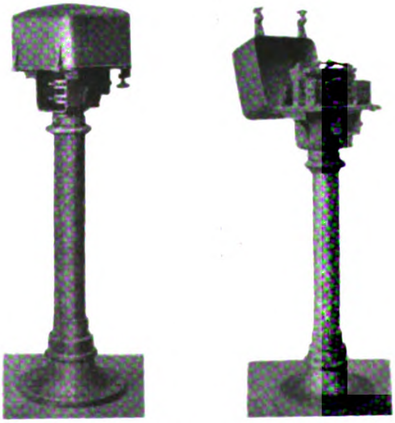


FIG. 1 TRANSMITTER OF ELECTRIC HELM INDICATOR.

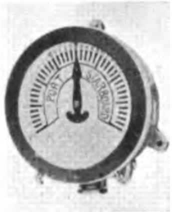


FIG. 2. RECEIVER OF ELECTRIC HELM INDICATOR.

of roller chains fitted to toothed wheels on the spindle of the transmitting switch. The spring couplings are provided to allow a certain movement of the rudder before the switch is actuated: this, together with a form of escapement gear, ensures that the movement of the switch is definite from one set of contacts to another, thus avoiding sparking and other contact troubles. Two sets of ropes, springs, and chains are provided, either of which is sufficient to do the driving of the switch. The switch is contained in a gun-metal case provided with a water-tight cover and separate terminal box, and mounted on a particular type of steering gear. All parts are very accessible and of substantial construction.

The indicator or receiver, Fig. 2, is a dial instrument, consisting of a gun-metal case with a water-tight front fitted with plate glass, and contains the magnetic motor for actuating the pointer. The dial over which the pointer moves is of opal glass for the purpose of affording internal illumination, and has on its surface the scale for indicating the movement of the rudder in degrees. The scale is of a very open and bold character, and embraces an angle of 120 deg., from "amidship" to "hard over."

The internal illumination is provided by a lamp, fitted with a special water-tight fitting which enables it to be readily removed, and which makes contact to the terminals of the lamp when placed in position.

The indicator case is provided with lugs for fixing to a bulkhead or other support, and has a polished front, and is fitted with water-tight cable glands. It can also be provided mounted on a column.

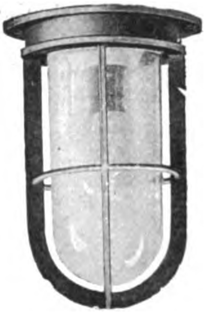


FIG. 1.

Electric Fittings for Ships.

Since William McGeoch & Co., Ltd., took over their present works in Birmingham, over a quarter of a century ago, they have been closely identified with the manufacture and design of all kinds of electric fittings fuseboards, switchboards, &c., for ships, and have made a speciality of this class of work. Of the very many examples of electric fittings which are required to serve the widely varying conditions of ship usage, those illustrated will serve as an index to the special designs which are called for in connection with marine work. Figs. 1 and 2 show a strong water-tight guarded roof fitting, and a gunmetal guarded pendant respectively. The latter has been adopted for Admiralty work, although it should be said that the type has been slightly modified recently.

Besides standard patterns of ship fittings and Admiralty fittings, a good deal of attention has of late years been given to the design and manufacture of special fittings for saloons, state-rooms, &c. Fig. 3 shows a successful pendant, which is used without a glass, whilst Fig. 4 shows a fitting

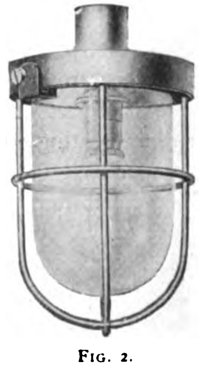


FIG. 2.

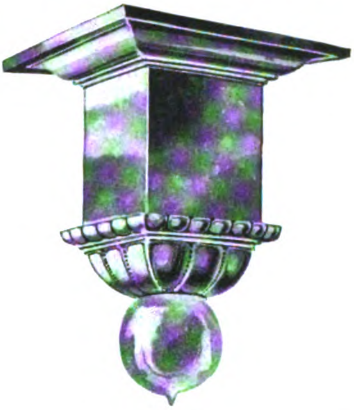


FIG. 3.

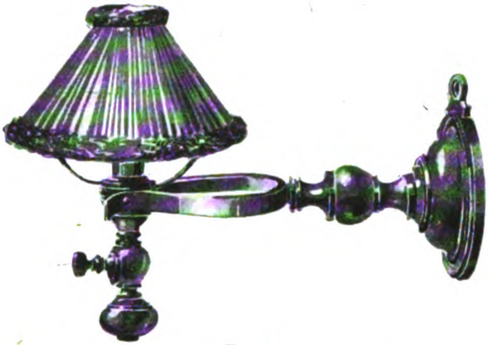


FIG. 5.

which has been very widely adopted. As will be seen, it is a large ceiling fitting with an obscured glass cover. A favourite fitting is also the Gimbal standard, such as shown in Fig. 5, which is very suitable for state-rooms, as it can be used either for writing tables, or for fixing on the walls. They are necessary where there are suites of rooms, embracing private writing and sitting rooms.

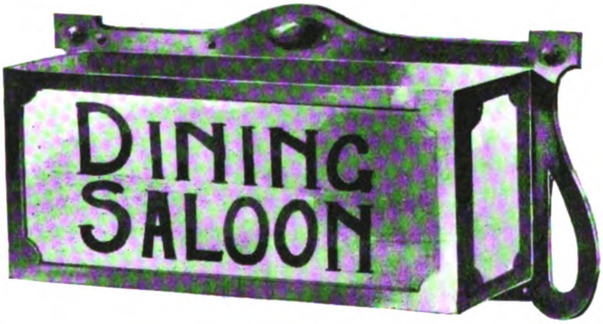


FIG. 6.

One of the latest developments of the Company has been illuminated sign lanterns, of which an illustration is given in Fig. 6. The one shown is for fixing on the bulkhead, but they are also made for suspending. They are of great advantage to passengers in locating any particular room. Sign lanterns of this type have been supplied to the latest Cunarders, Orient liners, &c., and are very necessary for all up-to-date passenger ships. Other specialities include a large variety of cast-iron hold fittings, cargo lamps and reflectors, cast-brass water-tight signal lanterns, ship glasses, cut crystal globes, and shades of all

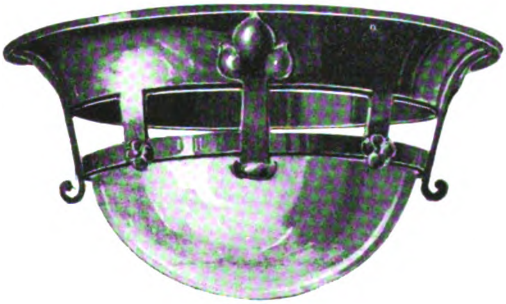


FIG. 4.

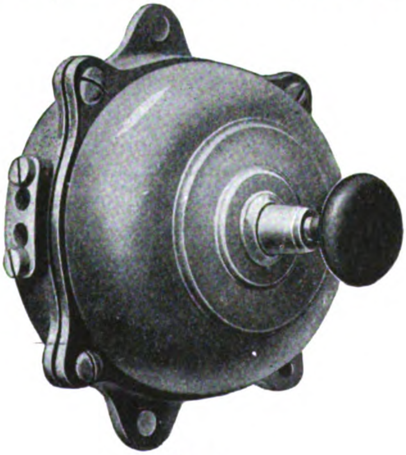


FIG. 7.

kinds, also Admiralty lighting and bell material. Fig. 7 is an illustration of a water-tight push for a single-stroke gong, which is made in gun-metal or aluminium.

A speciality now being put on the market is the "Wightman's patent masthead flashing lantern and Morse key." This lantern, owing to the arrangement of the lamps, can be used with a flashing key only and without condenser. This, of course, is a considerable saving in cost. A feature of the flashing key is that it has the Morse code on ground glass in the lid; this is illuminated by a small lamp inside which indicates whether the main lamp is flashing properly or not.

◆

Electrically operated Water-tight Doors.

Naval construction has developed the water-tight bulkhead, which, when properly carried out, has saved many a ship from sinking or at least has enabled her to remain afloat for a sufficient time to enable the lives of passengers and crew to be saved. In order that the ship may be conveniently worked, water-tight doors in the bulkheads are a practical necessity, and herein lies the possibility of danger. In the past, hand-worked water-tight doors, improperly closed or altogether forgotten by the crew in the excitement of the moment, have in cases of collision or grounding entirely nullified the value of water-tight bulkheads, and in consequence many lives and much valuable property have been lost.

It is desirable therefore that the human element should be eliminated as far as possible in a crisis such as the above, and for this reason the long-arm system of closing water-tight doors has been developed; after many years of experience of ships under sea-going conditions, with improvements made here and there as occasion has demanded, this system has been perfected in all its details, and is now in successful operation in a large number of men-of-war and other vessels.

General Requirements.

The general requirements of operation for any system of water-tight doors may be summarised as follows:—

They should be capable of being operated—

(*a*) Collectively or in groups from the bridge by power.

(*b*) Individually from either side of the door by power.

(*c*) Individually from either side of the door by hand.

With such a power door system, the captain or officer of the watch has the water-tight doors under his immediate control, and in cases of emergency can at once close all the doors in the ship without calling upon the crew, thus leaving the crew to carry out other important duties which are required when danger of collision or running ashore becomes imminent.

It is essential that the "emergency closure" does not in any way affect the easy opening of the doors locally by power, when any of the crew wish to pass through them in carrying out their duties or in escaping from below. After passage through the doors in such a case, the doors must close *automatically* and not depend upon the attention of the crew in this most important feature. Means for working the doors by hand are also necessary in cases where the ship is in dock with steam down.

Principal Features.

The following are the principal features of the long-arm system as developed by the British Thomson-Houston Company, Ltd.

(1) *The central emergency station* for quickly closing all the water-tight doors at will. This is placed on the bridge, under the eye of the captain or officer of the watch. Indicator lamps are fitted to show at any time the state of each door (whether closed or open) and in case of local obstruction to point out the door to be cleared.

2. *The liberty action* at each door, whereby a man at any door can open the door at any time during an "emergency period" (*i.e.*, when the emergency station is to "on") for

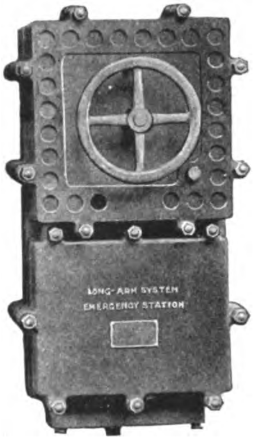
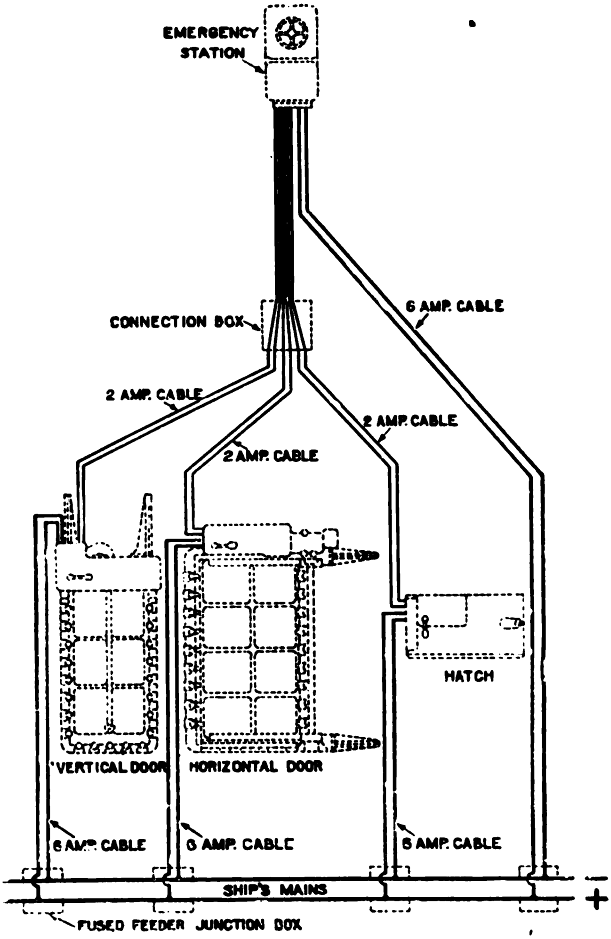


Fig 1. The Emergency Station.

escape, the door immediately closing automatically after any such action without further manipulation either locally or from the emergency station.

3. *The automatic cut-out*, at each door, whereby the power is continually weighed during operation, shutting off the current when an obstruction stops the doors, and automatically closing the circuit, and so resuming action the moment the obstruction is removed. Thus the danger of the apparatus being rendered inoperative by a burnt-out fuse is avoided.



AMPERAGE BASED ON 100 VOLTS PRESSURE

Fig. 3. Diagram of Electric Control Connections.

4. *Water-tight Doors.* — The doors themselves are of the most improved type for effective operation and water-tightness, each being provided with a specially designed electric motor and safety controller, whereby the door may be closed from the bridge, or operated locally from either side at any time.

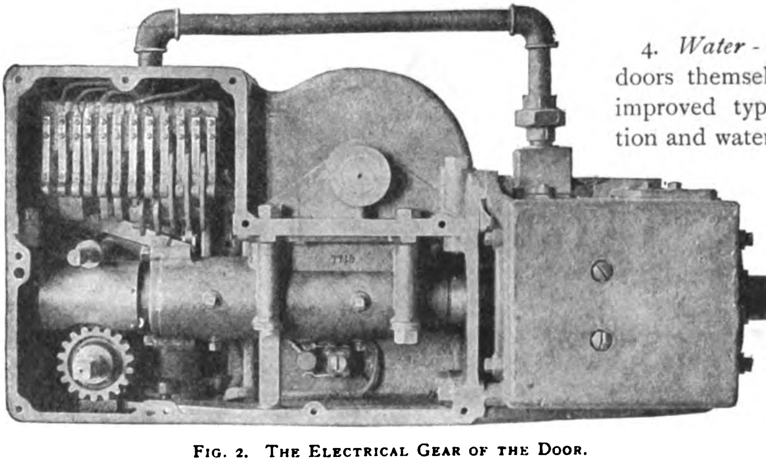


Fig. 2. The Electrical Gear of the Door.

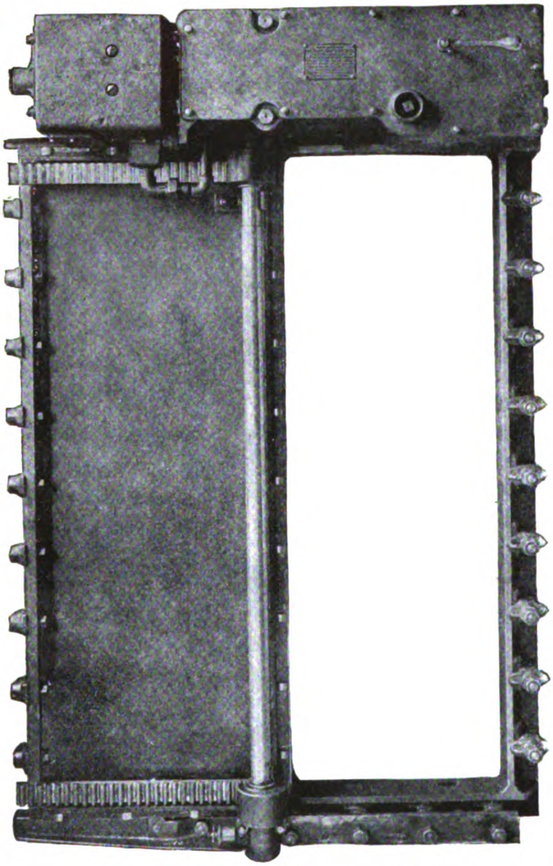


FIG. 4. ELECTRIC WATER-TIGHT DOOR.

solenoid circuits at about three-second intervals.

Each door and hatch may be opened locally by the use of the controller handle described elsewhere, and as long as the emergency is "on" they will re-close automatically as soon as said handle is released.

To turn "off" the emergency:—

1. Grasp the hand wheel and revolve in *left-hand* direction until the lug on the hand wheel strikes the notch projection on the cover.

2. Pull the hand wheel away from the case and rotate in the *left-hand* direction until the lug is opposite the notch.

3. Release hand wheel and the lug will enter the notch on the case.

The emergency station may be divided into three parts:—

1. The switching mechanism for controlling the circuits running to each door or hatch gear for closing the door or hatch.

2. The lamps to indicate the closure of each door or hatch.

Emergency Station.

In order to close all doors and hatches of the ship from the emergency station, the emergency must be turned "on" in the following manner:

1. Grasp the hand wheel at the rim and pull away from the cover of emergency station until the lug on the hand wheel clears the notch on the cover.

2. Turn the hand wheel in the *right-hand* direction until the lug passes over the notch projection.

3. Let go of hand wheel and the device will, without further attention, close all

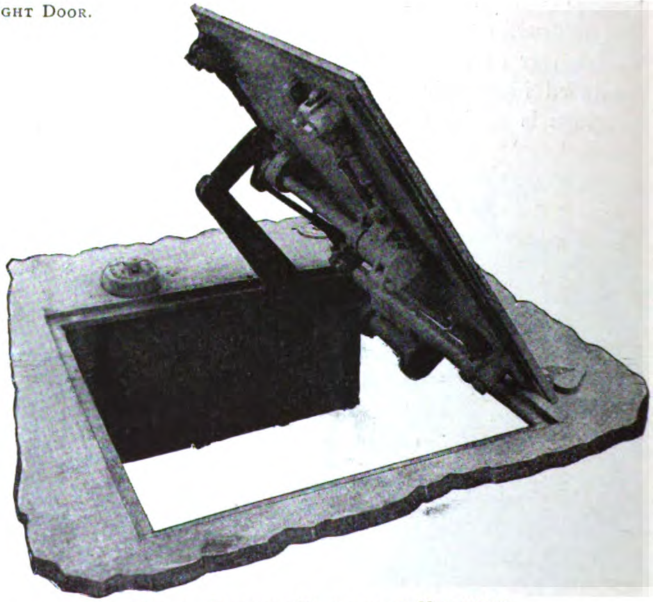


FIG. 5. ELECTRIC WATER-TIGHT HATCHWAY.

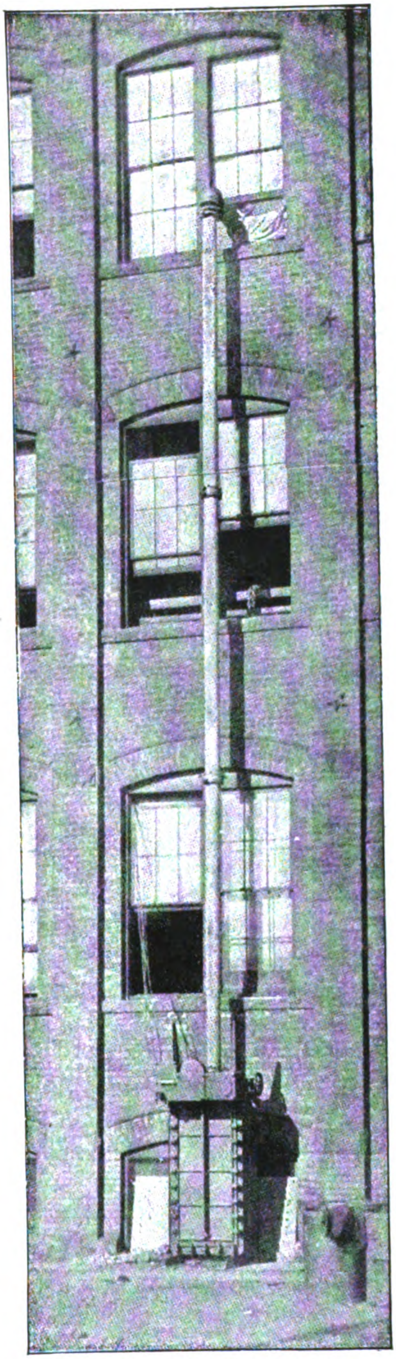


FIG. 6. DOOR ARRANGED FOR TEST.

3. The fuse box in which each wire entering the emergency station is supplied with the proper fuse.

The switching mechanism does not start all doors operated by the emergency station at the same time, as this would require a large amount of current from the ship's generator, especially in cases where a large number of doors are installed. The doors and hatches are, however, started one after another with an interval of about three seconds between them, so that the starting current for one motor will have died down to its normal running value before the next motor is started.

Owing to this "delay action" of the emergency station combined with the "automatic cut-out" on each door, the maximum horsepower required for the largest group of doors (twenty-four) is limited to about 5h.p. for a time not exceeding seventy seconds. The operation of a single door requires about $\frac{3}{4}$h.p. for about fifteen seconds. The "delay action" of the emergency station is controlled by a powerful spring and an escapement.

In order to give proper warning previous to closing the doors, a gong is rung at each door; these gongs are automatically controlled by the emergency station, and commence ringing before any of the doors begin to close, and the effective closing of each door is indicated at the emergency station by a lamp. After all the doors are closed all these lamps may be switched off at the emergency station if desired, and then it is only necessary to switch on the lamps to ascertain the state of each door.

The door is a self-contained unit: the substantial bulkhead frame, which completely surrounds the clear opening, acts as a bed-plate for the *entire* mechanism. All the operating gear, the motor and controller are contained in a cast-steel power-box secured to this bulkhead frame. The power-box is supplied with water-tight covers for protecting the mechanism from injury, and for keeping it clean and free from dust, &c. With such a construction it is impossible for any of the working parts to get fouled or out of alignment.

The local operation of the door by means

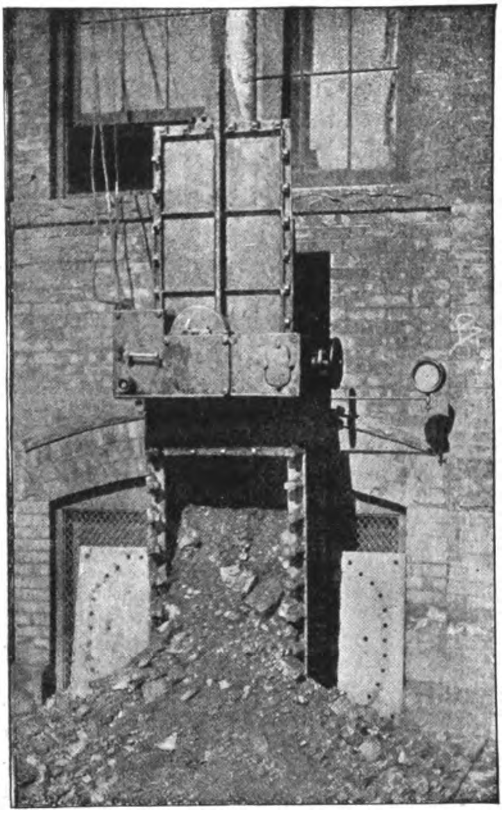


Fig. 7.

of the handle on the power-box is so simple. that an extended description is unnecessary The handle is normally held in mid-position by a spring, and to start the motor in either direction for opening or closing the door it is merely necessary to rotate the handle about its axis in the direction corresponding to that of the desired movement of the door. The door will respond and continue moving in the required direction only so long as the handle is held in the controlling position. The handle on being released automatically returns to the mid-position, and the emergency station if in operation will at once "take charge" and close the door again. The door can be worked locally from either side of the bulkhead.

Water-tight Hatches.

The water-tight hatch as illustrated has all he main features of the doors previously described, the only difference being in the design of the gearing and locking arrangements. The gearing occupies very little space around the hatch opening and practically none of the space in the clear opening itself.

Portable Test Plate.

A portable test plate can be supplied for each size of door fitted, and by this means the doors can be tested at any time for water-tightness under a head of water and any necessary adjustment made to ensure the door being tight. The leakage should not be more than 2½ to 3 gallons per minute under a head of 20ft.

An elaborate series of tests was devised by the U.S. Navy Department to ascertain whether these doors would close under all such conditions as might reasonably arise in practice, having particular reference to their

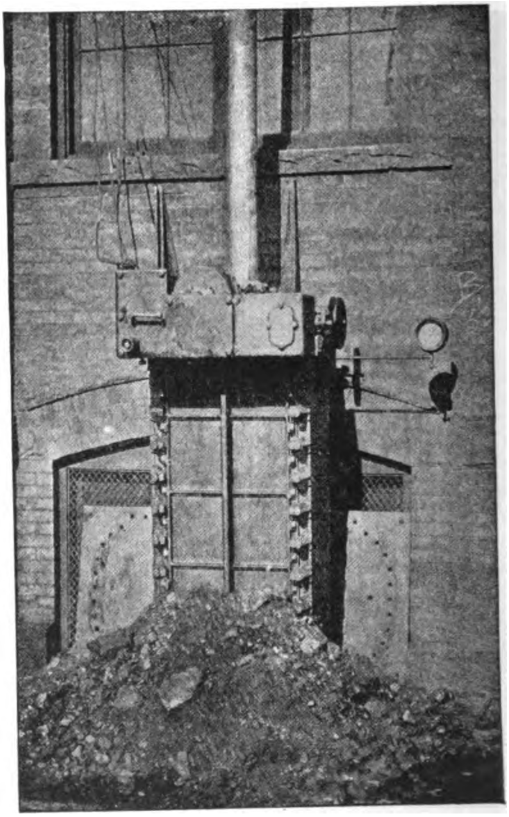


Fig. 8.

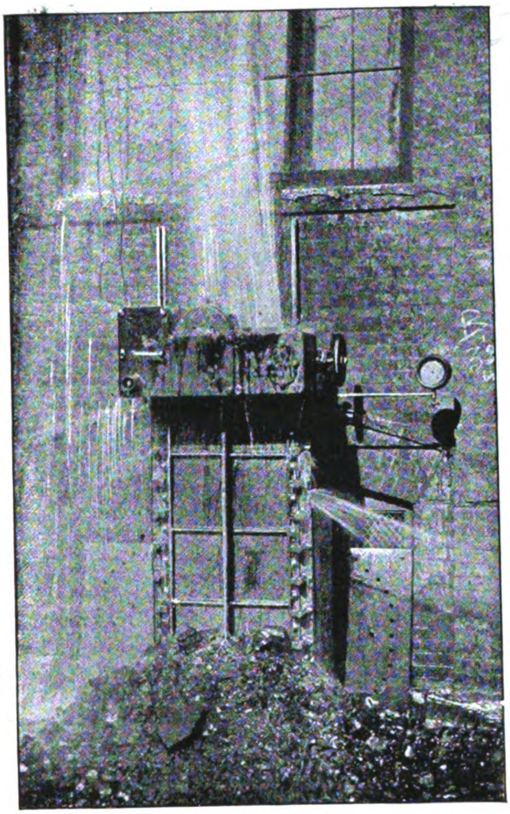


Fig. 9.

ability to pass through coal distributed over the sill of bunker doors.

For the purpose of the U.S. Navy Department's tests, the conditions existing aboard ship when the coal-bunkers are full and the doorways between the bunkers and the fire-room are open and choked with coal were reproduced. The test included also a reproduction of the situation which would arise in the event of a hull puncture admitting an inrush of water sufficient to sweep the coal through the doors.

Fanciful descriptions of "ponderous doors crashing through the coal" are responsible for much misconception as to the actual working of power doors under such conditions. As a matter of fact, no door has ever been built that would always cut through all the lumps of coal which might be in its path, and afterwards seat itself perfectly watertight. To be safe for the men working in the fire rooms a door operated from the bridge of the ship must close reasonably slowly, so that the men will have ample time to get out of its way.

In carrying out the tests of the U.S. Navy Department, the power door was secured to a steel box, see Fig 6, which was intended to represent a coal-bunker, and connected by a large pipe with a tank upon the third floor of the building. At the lower end of the pipe was inserted a valve for controlling the flow of water; and also a gauge for measuring the pressure in the box, which could, if desired, be continuously maintained at 15.2lb. per square inch (which is equivalent to a 35ft. head of water above the sill of the door).

The box upon which the door was mounted was filled with coal which was allowed to run through the door opening in

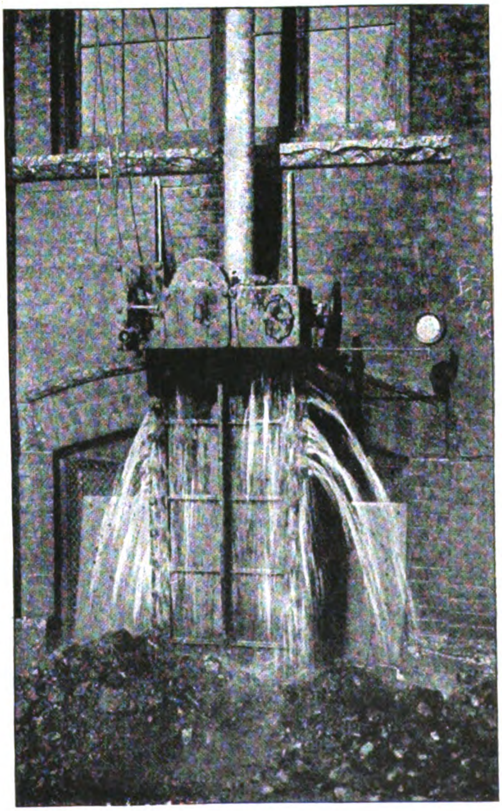


Fig. 10.

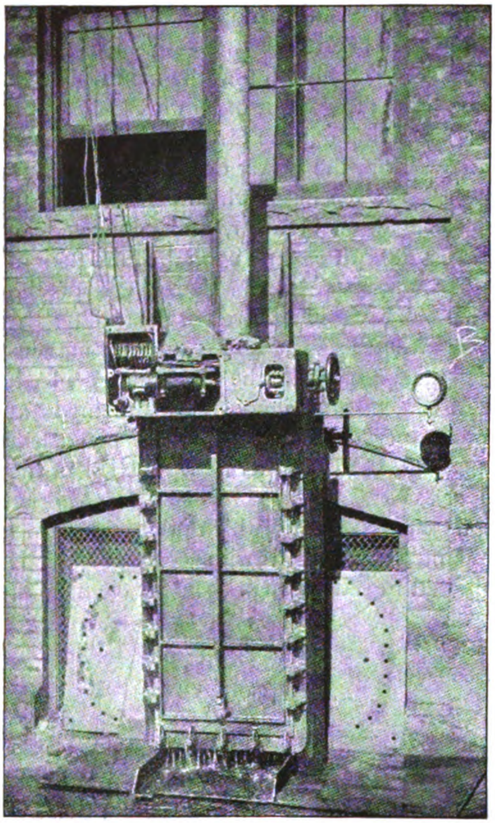


Fig. 11.

the same way that it would if the door were opened from a full bunker. Large lumps of coal were mixed with the layer of all sizes (see Fig. 7). Before closing the door upon this mass of coal, fine dust coal was shovelled and thrown up all over the tighteners and the frame, in order that the conditions of the test might be as severe as possible. To make the coal dust stick in sufficient quantity the bulkhead frame and tighteners were covered with thin oil.

The door was now closed from the bridge emergency station, the door plate cut through nearly all the coal, and the clear opening was almost completely closed when the automatic cut-out opened the circuit and stopped the motor.

In order to make this closure through coal possible, it is essential that the door-plate should work freely in sliding up and down, and not be forced against the bulkhead frame until it reaches nearly its final or water-tight position.

At this stage (Fig. 8), the door-plate was forced away from the bulkhead frame by the pressure of the coal and the clearance space between the door-plate and bulkhead frame was largely filled with fine coal dust.

After the door had closed into the coal, by the emergency station, and been stopped by the automatic cut-out, the water from the tank above was let into the box at the back of the door-plate and a head of 35ft. above the sill was maintained by adjustment of the valve. A thin film of spray worked its way through the clearance space between the bulkhead frame and door-plate, and in some places the water succeeded in washing out the fine coal dust which had collected (Fig. 9).

At this time the actual leakage measured less than 75 gallons per minute. The water at the back of the door-plate soon worked its way down through the coal to the slight opening at the bottom, and washed away the pile of coal in front, thus relieving the resistance to the thrust of the door plate which caused the automatic cut-out to throw in the current again, forcing the door to complete its closure (Fig. 10).

If the skin of a ship were so punctured as to admit water to one of her bunkers, its inrush would reach but one or at most two bunker doors, and if these doors happened to be open when the accident occurred and their complete closure was prevented by large lumps of coal over the sill, the total leakage due to the catastrophe would be dangerous. But if the doors were arranged to "follow down" automatically, and completely close, the leakage would be inconsiderable and could be readily taken care of by the usual pumps installed.

It was shown by the U.S. Navy Department tests that the cut-out gives to the door an almost human intelligence in its action when operated from the emergency station. For instance when the door closed into a mass of coal and struck lumps so large that it could not cut through them, the circuit to the

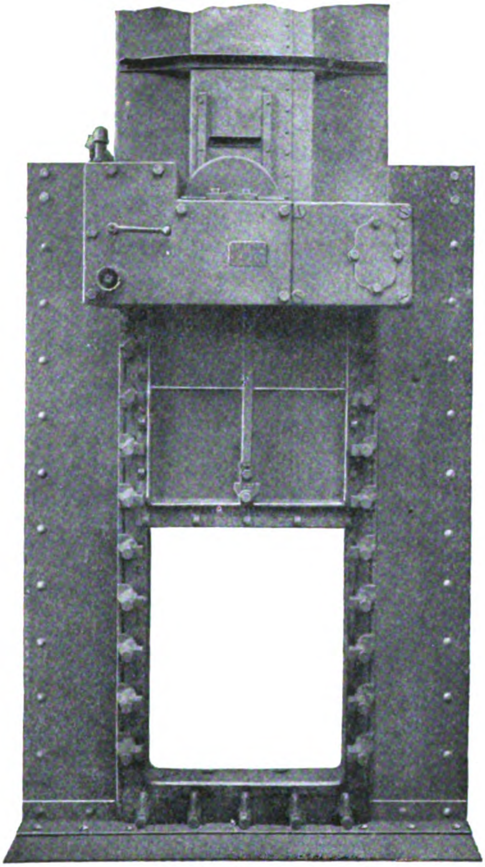


FIG. 12. DOOR PARTLY OPEN.

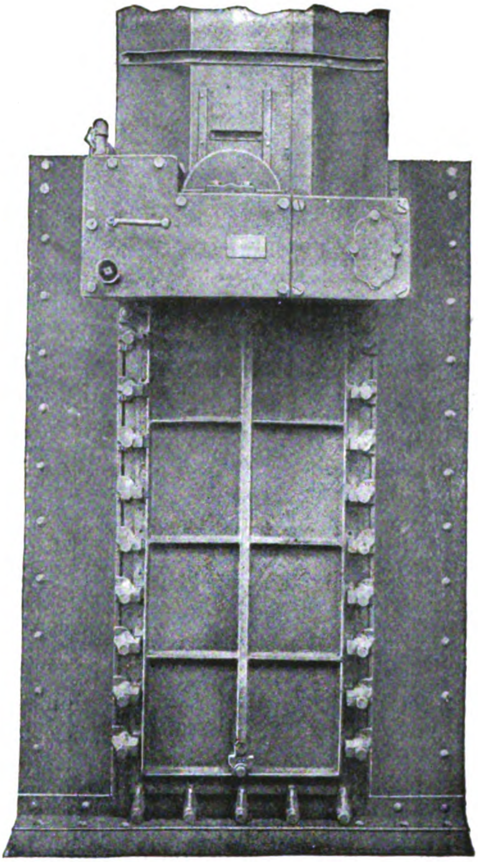


FIG. 13. DOOR CLOSED.

motor was opened; but nevertheless the device was not inoperative, for when water got into the bunker and loosened the mass of coal beneath the door-plate, the pressure upon the plate was relieved, the circuit again closed, the motor again started, and *complete closure of the door was effected* as if the work had not been interrupted.

At the conclusion of the foregoing tests all the coal was cleared away by hand, and Fig. 11 shows the slight leakage under a 35ft. head of water. As proof of the extreme practical value and efficacy of this apparatus, it is interesting to note that over nine hundred of the long-arm system of electric doors and hatches are in use in ships at sea.

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THE WORLD'S ELECTRIC PROGRESS.

Electricity for Ship Propulsion.

THE most remarkable feature of marine engineering to-day is the threatened change in method of propulsion, and it would, indeed, be no indiscretion to predict that electric propulsion is destined in the very near future to firmly establish itself as the only permissible system for modern craft. This sweeping revolution now pending is not the outcome of the momentary enthusiasm of a too sanguine and none too practical inventor—there are many engineers tackling the problem in detail, and their work has been in progress for years. Particulars of what has been accomplished in this direction up to date are given by Mr. Wm. P. Durtnall elsewhere in this number. Probably no one in this country has devoted himself so assiduously and successfully to electric marine propulsion as Mr. Durtnall; that his labours in this connection are fully recognised is evident from the recent records of marine and shipbuilding societies—wherever matters of marine design and the engineering equipment of vessels have been touched upon, Mr. Durtnall has shown that the electric motor is the correct power engine to drive the propeller. The main reasons of economy, flexibility, and high ship speeds are dealt with in the contributed article in a very full and complete manner, and need not therefore be discussed here. It should, however, be borne in mind that the main factor which makes the introduction of main electric propulsion for ships so imminent rests more with the recent important developments made in the design of prime-movers than in any particularly striking change in electrical motor design. Gas-engines, oil-engines, and steam turbines are the factors of to-day which are doing more to change power engineering practice on sea as well as on land than any change in the electric motor. Light-weights, cheap power, smokeless operation, extremely large generating units, ease of control, and greater reliability are all features of the greatest significance nowadays in power work, and all obtained by combining the above recent forms of prime-movers with electrical generating plant and motors. The power required on an ocean liner or first-class battleship for propulsion is enormous; these vessels are each great steam power houses—their streets of boilers and colossal engines are in themselves an enormous dead weight—the fuel is bulky, heavy, and expensive. One has only to glance at these oonditions as against those which might prevail when oil or gas is the fuel used direct in internal combustion engines, to realise that the prospect of such substitution is at least promising. To apply the power generated by internal combustion engines to the propeller shafts presents no difficulty when electrical transmission forms the connecting link, and also, of the greatest importance, the use of electricity permits of the main generating plant being disposed in any convenient part of the ship irrespective of the propellers. There is no reason why with electrical propulsion the main power should not be controlled direct from the upper deck or bridge of the vessel, and there is no longer any necessity for funnels and top impedimenta. What these factors mean to a man-of-war, and perhaps in a lesser degree to an ocean liner, is self-evident. Other advantages rest in the fact that the electric current generated in bulk can serve in the best possible manner for all other power-requiring services on shipboard. As said, this conversion of ship power entirely to electrical methods is imminent, and no subject is receiving greater attention from marine engineers and naval architects to-day. It behoves our manufacturers of large electrical plant to make a speciality of designing machines for this service and to prepare themselves for a branch of work which bids fair to be a vast field of industry in itself. As being the maritime nation of the world, the electric propulsion of ships is of the greatest import to this country, and doubtless everyone will read Mr. Durtnall's article with interest as, apart from its unique engineering value, it opens up a vista of vast commercial and political significance.

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Mining Electrical Engineers.

THE announcement that those electrical engineers who have to do with collieries and mines are to form an institution or society of their own will meet with general commendation, for there is much need of a standard of proficiency being established in this sphere of electrical power work which entails such exceptional responsibility. For their own protection and welfare these engineers require to have definite established qualifications, and it is very certain that the owners and managers of collieries and mines will encourage the innovation, for their troubles and anxieties have been frequent in the matter of "electricians."

The new institution is to be called "The Institution of Colliery and Mining Electrical Engineers," and is intended to comprise two classes of members:

(1) Colliery and mining electrical engineers, and (2) members of the Institution of Electrical Engineers who join for professional purposes only.

The following rules have been drafted to apply to the former class of members, and in the case of the latter class rules 1, 2, 3 and 4 will not apply:—

1. That each member must have been in charge of a colliery or mining electrical plant for at least one year, or have worked as assistant for at least two years previous to application for membership.

2. That each member shall be prepared to give a satisfactory reference or testimonial from present or past managers.

3. That each member shall be thoroughly acquainted with the Mines Regulations Acts, 1887, 1888, and 1896, relating to Electricity in Mines.

4. That each member must be prepared to pass a practical examination on Electrical Work by the Institution in order to hold a certificate of competency given by the Institution.

5. That no new member shall be admitted unless the Committee are absolutely satisfied that he is thoroughly experienced and fully competent to take charge of any colliery or mining plant.

6. That the Committee have the right to terminate a membership upon thorough investigation of wilful neglect of his duties or incompetency, or through any actions discreditable to the Institution.

7. That all the members shall work together for the benefit and goodwill of the Institution and other members.

The proposal is to hold meetings at various centres for lectures and discussions, and for hearing practical suggestions from members, one of the objects being to keep up a high standard of efficiency in workmanship and materials best suited to colliery and mining electrical work. So that there may be local representations in each mining section of the United Kingdom, the Committee members are appointed from various districts. A register will be kept of members who desire to change their situations in order that they may be recommended to colliery managers who are requiring competent men; several colliery managers have already signified their willingness to support this branch of the Institution work. We understand that a number of prominent men have undertaken to join the Institution as members, and Committee members have been chosen for Yorkshire, South Wales, and Lancashire. The honorary secretary and treasurer (*pro* *tem.*) is Mr. J. Williams, of the Moresby Coal Co., Ltd., Whitehaven.

It has not yet been decided where the headquarters of the Institution will be, but an inaugural meeting has already been fixed to be held in Manchester on April 24th. When the Institution gets into working order papers will be read in different towns at a centre of each mining district, and it is proposed that a monthly record should be sent to each member, containing reports of the meetings and papers. The subscription has been fixed at £1 1s. per annum.

Wireless Telegraphy and Telephony at Sea.

From the fact that it will soon be essential by law for all passenger steamers to carry wireless telegraph outfits, there are few electrical matters of the day which are of greater attraction to the general public. Mr. Maurice Childs, the author of the article in this number on wireless telegraphy as used on board ship, is connected with the London Telegraph Training College, and is not only well versed in the technicalities of his subject but is fully alive to its commercial side. The striking feature of wireless telegraphy for ships, as demonstrated by Mr. Childs, is the remarkable cheapness of the apparatus necessary for a complete installation which will efficiently serve for distances up to 300 miles or so. The simplicity of its operation is also a point well brought out, and shipowners who have been deterred from taking up the system on the score of its complexity and expense will do well to enquire more closely into the real merits of the wireless telegraph, which has now proved an entire commercial success, for navigation purposes at all events.

The round-the-world cruise of the American fleet afforded an extended opportunity for proving the respective values of the several new devices for communication at sea between ships, and some reports of the results are available. The methods included the semaphore, the submarine signal bell, the wireless telegraph, and the radio-telephone. Each of these proved successful from various view points, and under suitable conditions.

The wireless telegraph proved its value many times where great distances had to be covered, but the latest of all methods, the wireless telephone, is reported to have more than filled the expectations of the officers of the fleet. Its low power was often drowned out by the more dominant telegraph, but properly attuned speech is a factor that seems destined to fill a still more important part in communication at sea.

"Bakelite."

Under this name a new insulating material was introduced to the public at a recent meeting of the American Chemical Society, by Dr. Baekeland, and for which so many highly valuable electrical and mechanical properties are claimed that it demands the attention of electrical designers and manufacturers. The details of its manufacture are postponed publication until the discoverer presents a further paper before the American Electrochemical Society next month. So far, we have been told that it is a coal-tar product, resulting from reactions between formaldehyde and phenolic bodies under exceptional conditions of pressure. It is this latter feature of the inventor's research work which has led to the unique discovery of "Bakelite." The material is said to combine the best electrical features and properties of amber, ebonite, and celluloid. Although not as flexible as the last two materials, it is harder and stronger, and resists heat, all solvents, and most chemicals ; it is also considerably cheaper. It is insoluble and infusible, and does not soften even at a temperature of 350° C. At the temperature of melting glass it chars, but does not fuse. It is made both transparent and opaque, and can be mixed with filling materials such as asbestos, clay, or wood-pulp. Electric machine windings impregnated with the raw material and heated under pressure become encased in a hard, infusible insulating mass. The material is also used for making moulded insulators, which exhibit great strength mechanically and dielectrically, and also withstand high temperatures without softening. Inexpensive soft wood can be impregnated with the material and becomes as hard as ebony, a good insulator, and rot-proof. A coating of the material also gives a beautiful finish to wood, which is not affected by boiling in water, solvents, or chemical solutions. It has also been used for making self-lubricating bearings which can be moulded to shape and size; and it is also applicable as a piston packing owing to its capability of withstanding high-pressure steam and chemicals.

Physical Injuries Attending Wireless Telegraph Operating.

The March number of "Archives de Médecine Navale" contains an article by Dr. P. Bellile referring to the experiences of telegraph operators on the battleship *Descartes*, which, during the recent Tangiers Expedition, was called upon to undertake an exceptional amount of wireless correspondence.

The operators frequently complained of trouble with their eyes and disturbances of vision, and the author believes that this was due to the effect of the rays emitted by the spark employed for transmitting in the case of wireless instruments, being analogous to the well-known effect of incautious exposure to the naked arc-light.

In several cases defective visual acuity was experienced, and was ascribed to actual malformation of the eye lens arising from the action of these rays; so clearly did this injury appear to be due to the occupation of the sufferers, that a certificate to this effect was actually granted. Other symptoms were the appearance of a form of eczema on the hands and wrists of operators, and palpitation of the heart and other nervous ailments. In addition, one man suffered such a marked deterioration in eyesight as to exclude him from readmission to the service, and yet no actual physical injury could be traced in the eye to account for this defect.

The author suggests that the short, thick spark used in wireless apparatus, being particularly rich in ultra-violet radiation, is directly responsible for eye-trouble; continuous exposure to such sources, he thinks, may ultimately lead to deep-seated defects such as atrophy of the optic nerve. It is therefore proposed to provide operators with special forms of spectacles devised to absorb the objectionable radiation.

The question is raised as to whether the actual wireless electro-magnetic waves may not exert some injurious physiological action on those constantly living in their neighbourhood. The existence of such waves, easily conducted as they are by the metal framework of battleships, is readily demonstrated to those on board by the fact that sparks can often be drawn from the finger while the wireless apparatus is working. There are certain indications of nervous ailments on the part of sailors that have given some concern of late years, and these may prove to be due to this cause.

As the author remarks, it is singularly unfortunate that each development in physical science seems to be attended by the ultimate recognition of some at first unsuspected source of physiological injury, to be guarded against. This has been found to be true of other rays, and experience seems to be now demonstrating a corresponding quality on the part of the electro-magnetic telegraphy waves.

Electrically-driven Rolling Mills.

The new electrically-driven reversing steel rolling mills recently put to work at the works of Sir Alfred Hickman at Bilston have proved completely successful. A 36in. cogging mill and a 24in. finishing mill are now in operation. The main power is generated by gas engines working on blast-furnace gas. The generator current is supplied to a fly-wheel load equaliser consisting of a motor mounted on a common shaft with two cast-steel fly-wheels, each weighing 32 tons, and running at a speed of 300r.p.m. Upon this shaft there are also two generators, one of which actuates a motor which drives the cogging mill, and the other a motor driving the finishing mill. The engine power is only about 1000h.p., but the reserve stored up in the fly-wheels is sufficient to develop 12,000h.p. for short periods when required. The action of the mills is reversed simply by moving a lever, and the whole machinery, running at 120r.p.m., is reversed in about six seconds from full speed in one direction to full speed in the reverse direction.

* * *

Steel Driving Belts.

THE development of steel belts for heavy power transmission service is of more than passing interest to electrical power engineers. Valuable particulars have recently appeared concerning the development of the Eloesser-Kraftband-Gesellschaft, of Berlin, in this direction.

As would naturally be expected, the joint or splice of a steel belt is one of the critical features. The joint construction used by this firm consists of two steel plates, an under and an upper, between which the ends of the belts are joined. These plates taper from a thickened section at the centre to comparatively thin edges. Both the plates are shaped to a circular arc, whose radius is equal to the radius of the small pulley on which the joint is to be used. Thus, for a given joint there is a minimum limiting diameter of pulley on which it can run, but no similar maximum limiting diameter.

The belt itself is made of a uniform quality of steel of an even thickness and is tempered. The ends are carefully brought together, fitted and soldered with a special solder that flows at a comparatively low temperature. This joining is then placed between the two plates and these plates fastened together by means of screws.

A number of interesting claims are made for these belts. Three of the most striking are: The small amount of slipping of the belt on the pulley, given in figures as less than 1-10th of one per cent.; the narrow width of the belt compared with leather belts, the proportion being about 1 to 5; and the great speed at which these belts can be run, given as 100 metres per second, or say 19,000 feet per minute. This latter figure is striking if we compare it with the factor usually given for leather belting as 4000 feet per minute. It is very common to run these steel belts at a speed of 50 metres per second, or say, roughly, 10,000 feet per minute.

Other minor advantages which are really dependent upon the three major ones that we have pointed out are: A narrower and lighter pulley for given service, a lighter and smaller shaft, a reduction of the strains upon bearings (thereby a reduction of the size of bearings, and in many cases—especially on electrical machinery — the elimination of outboard bearings), a saving of room through a reduction of the general dimensions of machinery, avoidance of temperature and humidity effects (thereby a lessening of the required attendance), and, in case the belt is applied to existing pulleys, the possibility of using the pulley face for other belts. This last feature is particularly true of portable engines.

Because of the high permissible speed these belts have been adapted in many cases to electrical machinery, both generators and motors, and to gas engines. They have also been used for driving belts in machine shops and other manufacturing establishments.

* * *

The
Electrical Magazine.

VOL. XI. NO. 5. MAY 15th, 1909.

ENGLAND TO INDIA BY DIRECT TELEGRAPH.

IT was Kipling who wrote in his "Ballad of East and West" that

> East is East, and West is West, and never
> the twain shall meet
> Till earth and sky stand presently at God's
> great judgment seat—

which only goes to show that Kipling and the Indo-European Telegraph Company, Ltd., look at the problem of the Far East from different points of view. On Saturday, January 23rd of this year, Madras and Manchester, Rangoon and Liverpool were linked by a system of direct telegraphic transmission. At a demonstration at the London station of this telegraphic company a message was received from Karachi (5342 miles) at the rate of forty words per minute, followed by a telegram from Calcutta (6967 miles) at fifty words per minute, which was automatically retransmitted to Liverpool and Manchester. Then came a directly transmitted message from Bombay (6562 miles); this was succeeded by messages received from Madras (7356 miles) and Rangoon (7970 miles). The last-named was rightly regarded as a particularly noteworthy achievement, owing to the difficulties from an electrical point of view presented by much of the 1000 miles of country between Calcutta and Rangoon. This is the commencement of a speeding-up of telegraphy to our Indian Empire which is of constant and vital importance.

MR. T. W. STRATFORD-ANDREWS, MANAGING DIRECTOR OF THE INDO-EUROPEAN TELEGRAPH COMPANY, LTD.

The Indo-European Telegraph Company's lines, starting from London, pass to

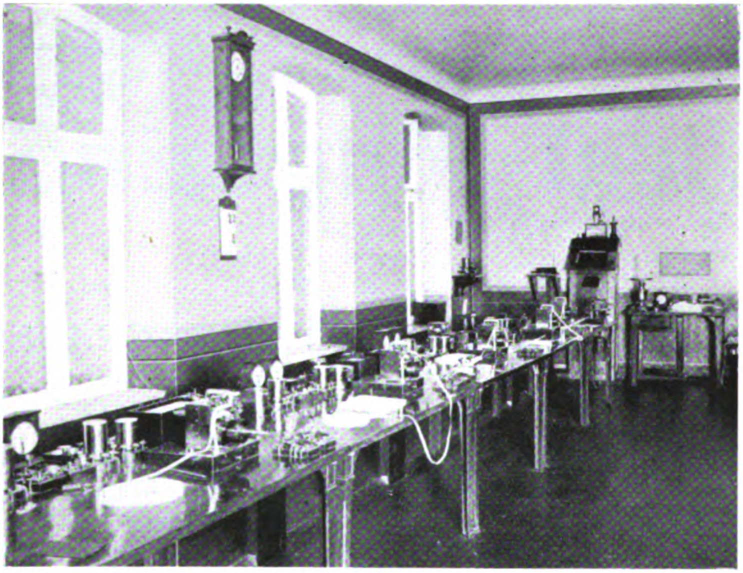


Fig. 1. Interior of Instrument Room at Warsaw.

Lowestoft, and, passing along the bed of the North Sea for about 250 miles, emerge at Emden to enter upon their long overland route stretching through Berlin, Warsaw, Rowno, Odessa, skirting the Black Sea by way of Kertch, and passing into Asia by way of Suchum, Tiflis, Tabriz, on to Teheran, 3800 miles having been covered up to that point. In 1907 Mr. H. A. Kirk, the Director-in-Chief of the Indo-European Telegraph Department of the Indian Government, instituted a land telegraph service between Teheran and Karachi by way of the Beluchistan frontier, which promised a valuable alternative route to the existing mixed system of land lines and cables between the same points via Ispahan, Bushire, and the Persian Gulf cable. Karachi is the tapping point for the Indian Government telegraphs, and there is now therefore a complete land-line system of communication between the great cities of India and our own important centres.

When it is stated that direct working has been established between London and India, this means that there are no intermediate re-transmissions; the London signals come out instantaneously in India. This constitutes a world's record for direct telegraph work, and is due to the combined industry of the Indo-European Telegraph Company and of the Indo-European Telegraph Department of the Indian Government.

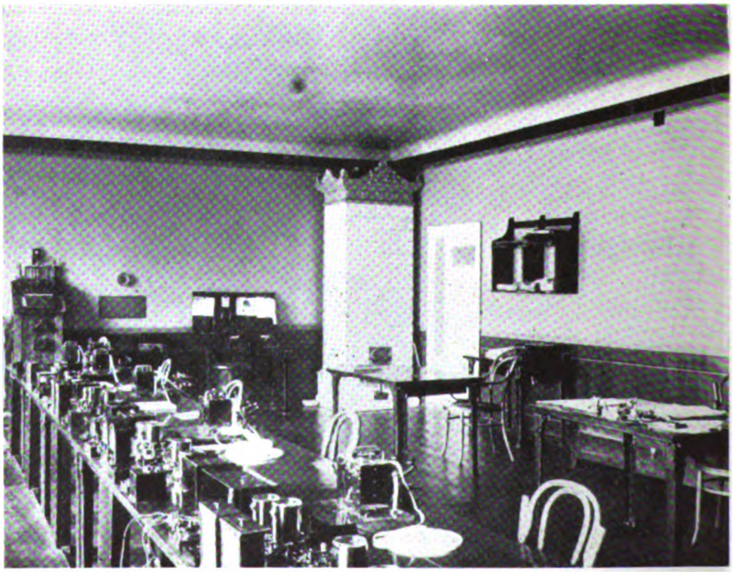


Fig. 2. Interior of Instrument Room at Warsaw.

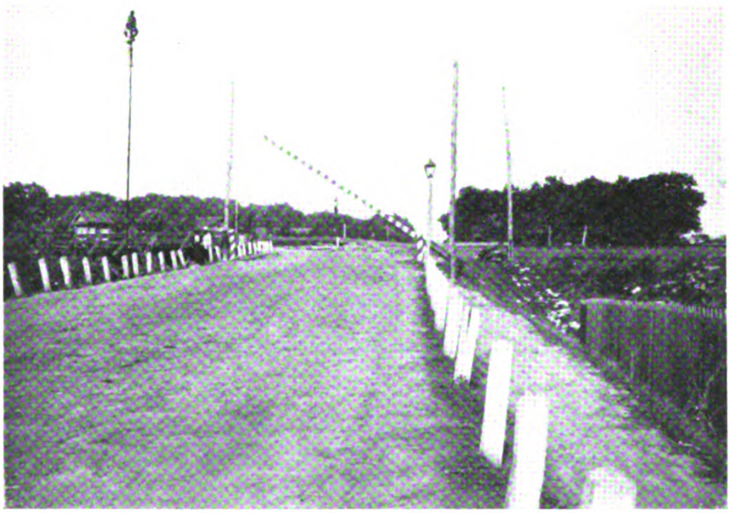


FIG. 3. POLE LINE PASSING THROUGH EKATERINODAR.

The accomplishment of this object, although it may appear very simple on paper, has taken years of patient work. Mr. T. W. Stratford-Andrews, the managing director of the Indo-European Telegraph Company, introduced at first Wheatstone working over short sections of the Company's line, the system being experimentally introduced on the Odessa-Teheran section in the summer of 1897. The experiment showed that signals could be satisfactorily transmitted in both directions on this section, and as the clerks became efficient in punching the slip and certain alterations were introduced at the relay stations Teheran could block Odessa with homeward messages. The Wheatstone system was then introduced on the Odessa-Emden section, and the two sections were then amalgamated by working direct from Teheran to Emden. It was found, however, that this blocked the Emden to London section, and the necessity of further extension of the Wheatstone working was obvious. Before, however, this could be done on the Emden to London section it was necessary to show the German and English postal authorities that no disturbance would be caused by induction to the other circuits in the cables between Lowestoft and Norderney and Borkum respectively. This was because the company only used one of the conductors in each of these cables. After

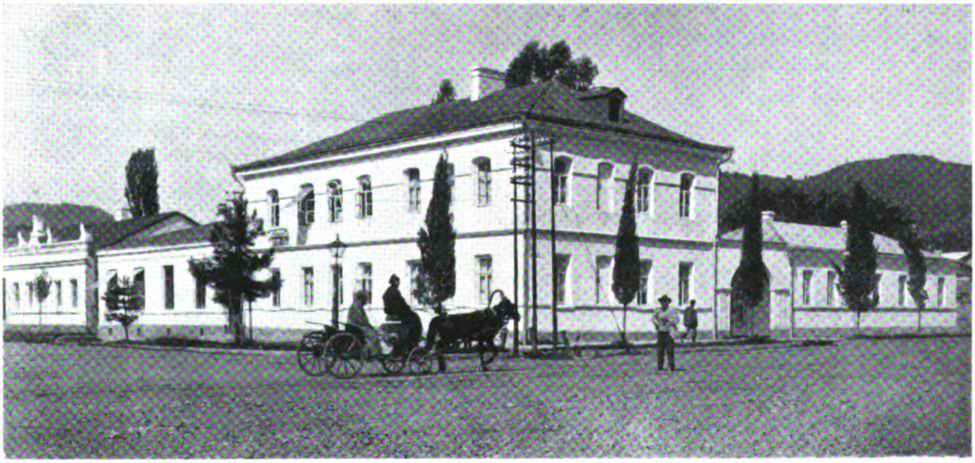


FIG. 4. THE SUCHUM STATION OF THE INDO-EUROPEAN TELEGRAPH COMPANY, LTD.

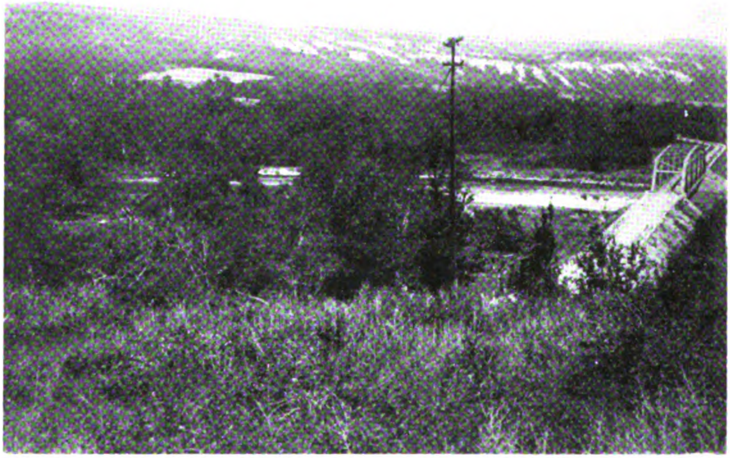


Fig. 5. Crossing the River near Djoulfa.

tests had clearly demonstrated the fact of non-interference experiments were made between London and Teheran, a distance of about 3800 miles, which showed conclusively that direct Wheatstone working could be thoroughly relied upon, and the system was finally introduced on January 1st, 1903, doing away with the original two re-transmissions at Emden and Odessa.

The next step was the transmission of messages arriving in London from Teheran by relay direct to Liverpool and Manchester respectively, instead of gumming the slip in London and re-transmitting it by Morse, and the signals arriving in these places were as clear as under the previous arrangement. Manchester and Liverpool stations were enabled to exchange their messages direct with Teheran, a distance of about 4000 miles, and key-work on the company's system is thus practically abolished except for the purpose of repetition, checking the number of messages sent and making any corrections. The number of relays in operation on this line between London and Teheran are ten, these being automatic with systems of translation which necessarily differed according to the date of introduction, and the varied requirements and conditions of the different sections of the line. The relays are of the Post Office standard "B" type, manufactured by Messrs. Siemens Brothers, and the Siemens relay with improvements added by the Indo-European Company. A Wheatstone receiving instrument is placed in shunt with the relays, and by putting this in circuit the clerks are able to maintain a perfect system of control. Provided that the line is in good electrical condition after the marks leave one station perfect, and the clerk at the next station finds the marks faulty, he knows his regulation is at fault, and is able

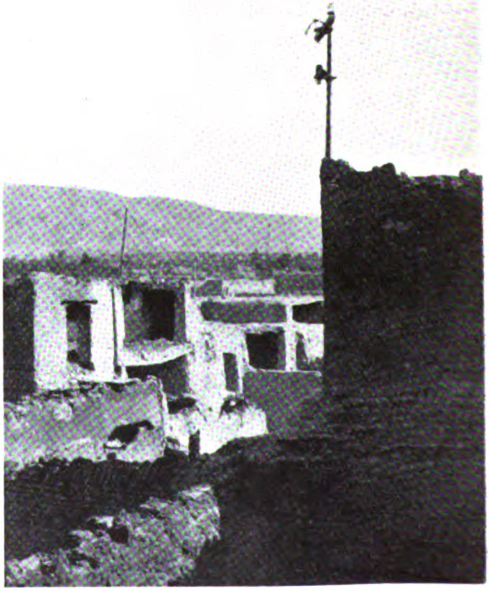


Fig. 6. Pole Line in the Midst of Ruined Bazaars at Tabriz.

to adjust his relay until the marks on his slip are perfect.

In order to estimate the value of the physical difficulties overcome, it is necessary to examine in some further detail the nature of the ground traversed. From London to Lowestoft the company use two land wires, which are leased from the General Post Office. At the latter station these wires are connected, one with a conductor in the Norderney cable, and the other with one in the Borkum cable. These two circuits connect Lowestoft with Emden on the coast of Germany. From this point Germany is traversed by land wires leased to the company by the German Government. As Germany is of course a highly civilised country no particular features of interest in the way of mechanical or electrical difficulties attach themselves to this portion of the route. At the Russian frontier, near Thorn, the German State wires are connected to special lines passing through Warsaw and Rowno to Odessa, and thence through the Steppes and the Crimea to the Straits of Kertch, this line being erected in 1868 by Messrs. Siemens Bros. Three submarine cables conduct the circuit across the Straits and the lines then pass through thick forests and rugged country along the North Eastern coast of the Black Sea to Tiflis. Passing south the boundary between Russia and Persia is at Djoulfa. From the frontier a stretch of desert land is passed en route to Tabriz, the old capital of Persia, and thence to Teheran. In the Caucasus the chief difficulty in line maintenance is the dense nature of the forests through which it passes, rendering a constant system of maintenance and forest clearing necessary, and a rather extraordinary cause of contact is the immense flocks of wild geese which periodically migrate. The most annoying trouble, however, is a very severe form of hoar frost, called "reifeis," which collects on the wires and even forms a sheet of ice from one conductor to the other. When this is accompanied by wind the wires are broken and even the iron posts are bent down, and the spacing between posts has had to be considerably reduced, adding to the capital cost of the line. In Persia the

Fig. 7. Group of Persian Natives and Soldiers.

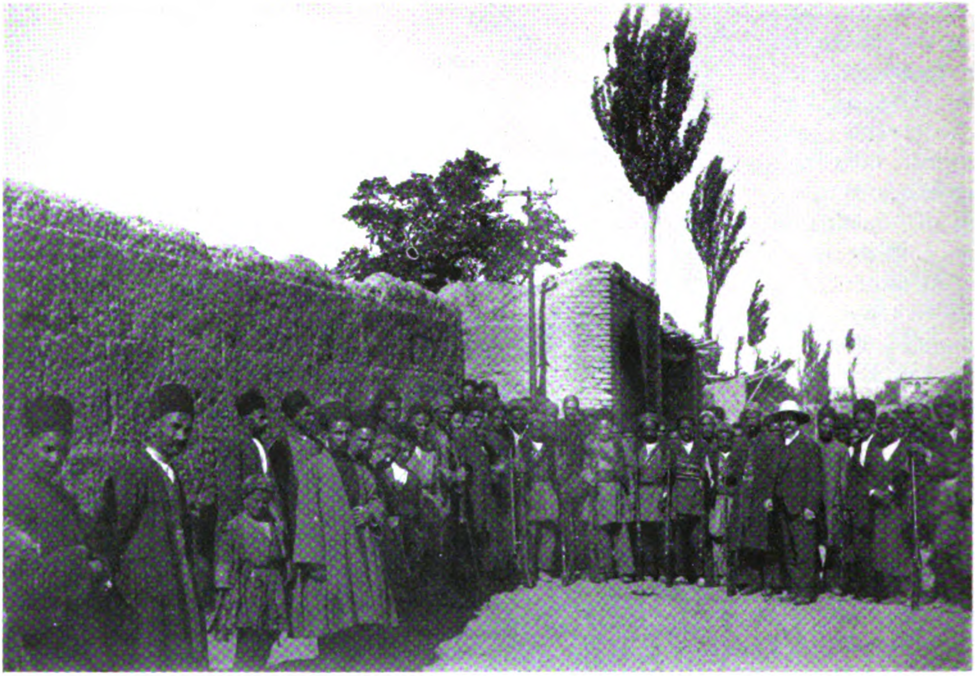


FIG. 8. GROUP OF PERSIAN NATIVES AND SOLDIERS.

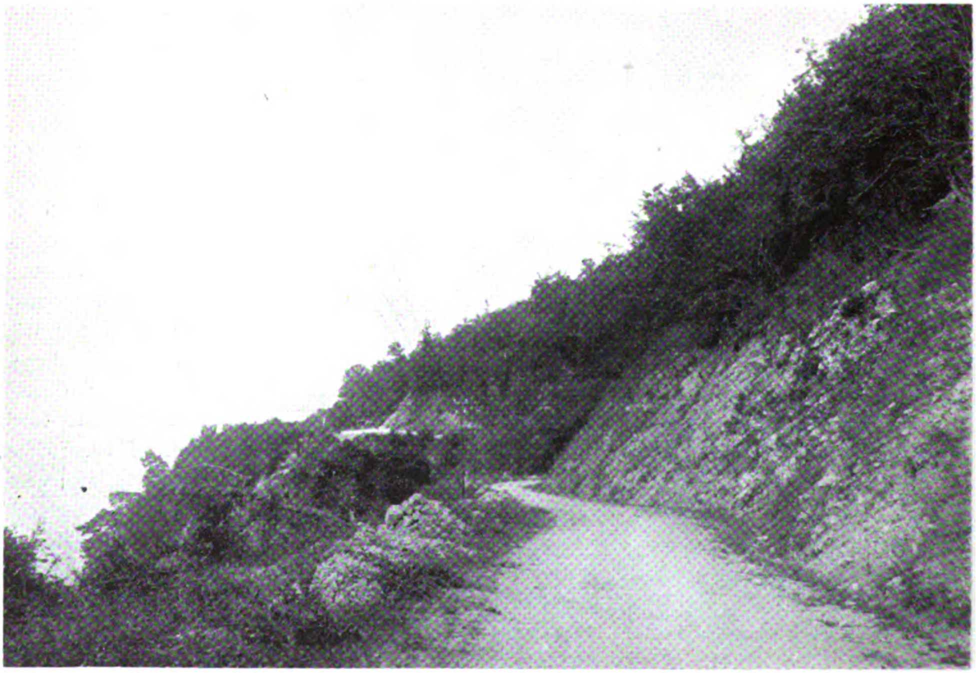


FIG. 9. INDO-EUROPEAN TELEGRAPH COMPANY'S LINE NEAR GUDAUT STATION.

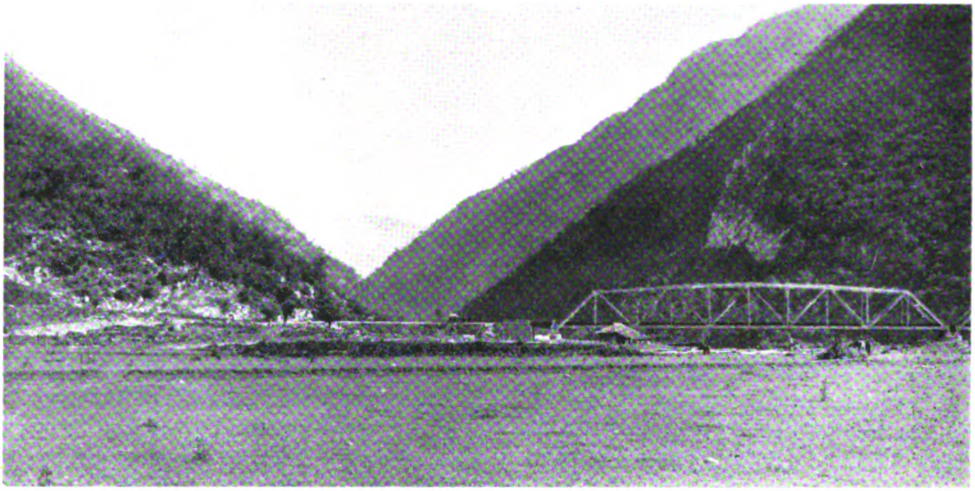


FIG. 11. CROSSING THE BSIP RIVER.

difficulties that have been met with are due chiefly to the unsettled state of the country. As is well known, Tabriz, through which the company's lines pass, has been in a state of siege for months, and communication has been repeatedly interrupted in the encounters between the two opposing parties. It is only with the greatest difficulty that the company's staff, at great risk to their lives, have been able to keep communication open. Owing to the destruction of the lines by the attacks of warring factions at Tabriz, a special line skirting the town had to be constructed, but it has been found that both the revolutionary and constitutional parties have regarded the line with a certain amount of respect, as they appear to appreciate the advantages of communication with civilisation. However the insulators offer a mark for the wandering troops of Persia to practise upon, and their skill with the rifle, together with the large round bullets which they employ, do a considerable amount of damage to the insulators.

FIG. 10. PASSING THROUGH FOREST COUNTRY NEAR PSOU.

A series of control stations are maintained along the entire length from the Russian frontier to Teheran, and in the more disturbed sections these stations are spaced only some twenty to twenty-five miles apart. Whenever a fault occurs, whether from natural or human causes, the controllers of the station affected are ordered out to remove the trouble at once, and in some cases this constitutes a matter calling for their utmost tact and energy.

Mention was made above of the land line constructed by the Indian Government between Teheran and Karachi. Between these two points there are three further relay stations which transmit the messages automatically, while communication between Karachi and Calcutta is maintained through a further relay at Agra. The final point in the development was reached when the manual re-transmission, which was before necessary at Teheran between the Government section and the Company's section, was done away with on January 23, and Wheatstone working can now be carried on automatically from points as far away as Calcutta and Bombay direct to Manchester and Liverpool, though as a matter of expediency in direction of the traffic the daily direct working is limited to the section London (Manchester and Liverpool)—Karachi. It is found at present that one through wire is capable of transmitting and receiving all telegrams between India and this country, a second wire being used for Continental and local traffic. Not only has the time of transmission been reduced practically to a minimum, but traffic is not affected by short interruptions to anything like the extent which occurred on the old system, inasmuch as owing to the great speed at which communication can be made messages are punched during the intervals of interruption and are transmitted in long strings at a rapid rate, as soon as communication is restored. The messages to be sent are punched automatically by telegraph operators on to a paper tape which is run through the transmitting instrument. At the first relay station signals bring a fresh battery into work in synchronism with their impulses, and thus the signal is re-transmitted automatically to the next station. This is carried on through a series of thirteen stations until the signal is finally recorded in Morse script at the receiving end.

We have pleasure in showing a series of photographs which illustrate among other

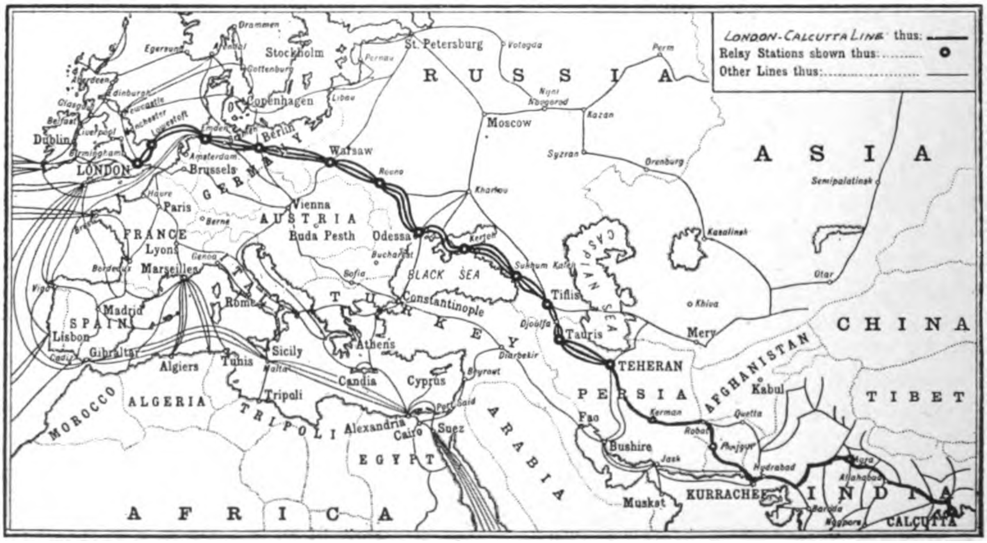
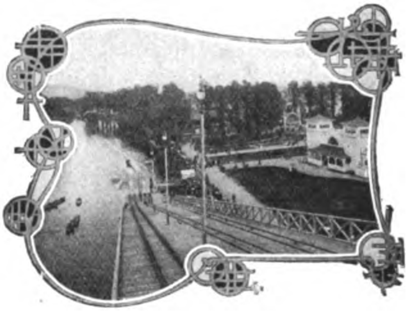


FIG. 12. MAP SHOWING THE LONDON-CALCUTTA LINE OF THE INDO-EUROPEAN TELEGRAPH COMPANY.

things the type of country through which the line passes. No special features of interest occur until the stepping-off point at Warsaw is reached, and Figs. 1 and 2 illustrate the instruments room at Warsaw. Fig. 3 shows the pole line constructed at Ekaterinodar on the North East coast of the Black Sea, while Fig. 4 shows the exterior of the station at Suchum. Fig. 5 shows the line as it passes across the frontier at Djoulfa, while Figs. 6, 7 and 8 show typical views near Tabriz. Figs. 9 and 10 give some impression of the forest country through which the line has to pass, the former being a view near Gudaut station and the latter near Psou station. Fig. 11 shows the Bsip river, near the Indo-European Telegraph Company's station, the company's line passing in the form of a long steel strand across the gorge.

These sufficiently well indicate the difficulties which would have to be encountered in making it possible to communicate with the Far East, and Mr. T. W. Stratford-Andrews, whose photograph we have pleasure in reproducing at the beginning of this article, may be complimented on the energy and enterprise of the company of which he is managing director.



THE USE OF SYNCHRONOUS MOTORS FOR POWER FACTOR CORRECTION.

THE use of synchronous motors for power-factor correction has proved in the majority of cases to be the cheapest solution of the problem of overcoming the bad effects of the large wattless currents which are inseparable from alternating-current power circuits, and for this reason these machines now play a most important part in the economical working of power stations. It will be generally admitted that it is not a difficult matter to find modern plants operating at a combined power factor as low as 70 per cent., so that an economical method of raising the power factor is highly desirable in such cases.

Before dealing with methods of calculating the capacity of synchronous motors required for any given supply circuit, it will be well to consider the working conditions which give rise to a low power factor in the system. As is well known, a low power factor is caused by leading or lagging currents—generally the latter - in the circuit, and one of the chief sources of a low power factor is the supply of power to induction motors. The current taken by these machines is made up of two components : (*a*) an energy component which is in phase with the applied voltage and gives true energy ; (*b*) an inductive or magnetising component which lags 90deg. behind the impressed voltage, and, being wattless, gives no energy. This wattless component is the cause of a low power factor, which in turn is the cause of (1) bad regulation of the supply circuit due to the demagnetising effect of lagging currents on the generator field ; (2) an increase in the heating losses in the generator and transmission circuits, the generator losses being increased owing to the fact that it is necessary to increase the generator field current above the value required to give any particular load amperes at unity power factor, when the same current is required at a lower power factor. A large wattless current in the system will therefore greatly increase the generator output necessary for a given amount of true power. The working vector diagram of an induction motor is shown in Fig. 1, in which AC represents that portion of the total current which lags behind the applied voltage AV by the angle ϕ. If a perpendicular be dropped from C_1, then AC will represent the energy component of the current, which is in phase with AV_1 and CC_1, the wattless component which lags 90deg. behind AV, the power taken by the motor being = AV × AC The power factor of the system supplying such a load may be raised to unity if the wattless component CC_1 is neutralised, and this can be effected by introducing a leading current CC_2 into the circuit. The total current in the circuit will then be the load current AC, and as this will be in phase with the applied voltage, the power factor will be unity. As already stated when dealing with the operating characteristics of a synchronous motor in these columns (see ELECTRICAL MAGAZINE, February, 1909), it is possible to run such a machine with a leading current by varying its excitation, and this fact at once suggests a method of improving the power factor of a transmission system which supplies an inductive load. This method of compensating for the large wattless currents inseparable from such a load consists of installing a synchronous motor at the receiving end of the line and adjusting its excitation until the leading current taken by it exactly balances

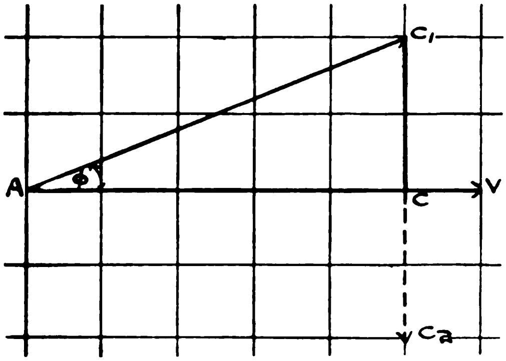


Fig. 1.

the lagging currents taken by the load; that is, if the power factor is to be raised to unity. The lagging currents due to the load will then only flow in the local circuit formed by the synchronous motor and the load, while the load current will be exactly in phase with the voltage of the system. When a synchronous motor is installed at the generating end of the line, although it will reduce the wattless currents on the generator, it will not improve the working conditions of the transmission line, which cannot be neglected for the following reasons:—The effect of large lagging currents and consequently a low power factor in the system is to increase the line drop for any given value of true power; also, the line loss due to the increased current caused by a low power factor increases as the square of the total current, so that the line loss increases in much greater proportion than the decrease in the power factor.

There are two methods of using a synchronous motor for compensating purposes; viz, (1) by running the machine light and excited to give a leading current; (2) by running the machine for improving the power factor and at the same time making it give out mechanical power. When considering the advisability of employing a synchronous motor for improving the power factor, the following questions arise:—

1. What advantage is to be derived, so far as correcting the power factor and its effect in reducing the generator load is concerned?

2. What is the advantage in making the motor give out mechanical power in addition to correcting the power factor?

3. What is the most efficient value to which the power factor should be increased?

The first question is important in the case of small plants where, generally speaking, it is more economical to install generators having a kilo-volt-ampere rating at the power factor likely to be obtained on the system, and especially is this the case where a motor could only be run light without delivering a mechanical output. As regards the second question, power factor correction is most economically carried out when there is a mechanical load available for the motor: but in some cases, however, this economy is gained at the expense of good operating conditions. On the other hand, when a motor is not mechanically loaded, its capacity required for obtaining unity power factor in a system would be very large compared with the increase in the capacity of the plant due to the increased power factor.

As regards the most efficient point to which it is best to raise the power factor, it is not advisable to raise its value higher than 95 per cent. from the point of view of economy. The combined power factor of plants supplying an induction motor load varies from about 60 per cent. to 80 per cent., and, in many cases of a low power factor, this is generally due to motors being under-loaded.

Having briefly considered the question of low power factor in systems and its bad effects on the operating conditions of the same, it will be of interest to consider some methods of graphically determining the capacity of synchronous motors required to raise the power factor to various values under different operating conditions, and for this purpose the following examples are given:- Suppose 500k.v.a. is delivered to a circuit at 70 per cent. power factor, which is to be increased to unity, and it is required to find the capacity of the synchronous motor to be used for this purpose. These conditions may be represented graphically

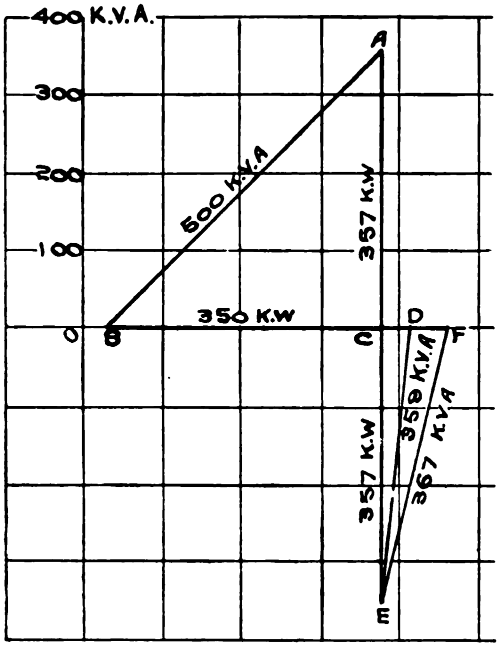


FIG. 2.

by the diagram in Fig. 2, which is an adaptation of that given in Fig. 1.

Referring to Fig. 2 the 500k.v.a. load on the generator is represented by AB, which represents the direction of the current, and as the power factor of the load is 70 per cent., the true power delivered will be: 500 × .7 = 350kw., this being represented by BC, which also gives the direction of the voltage. The wattless component of the load = $\sqrt{500^2 - 350^2}$ = 357kw., and as this is lagging 90deg. behind the applied voltage, it is represented by AC. If the power factor is to be increased to unity, it is necessary to neutralise this wattless lagging component by introducing an equivalent leading component into the circuit, and as this component is 90deg. ahead of the applied voltage as regards its phase it will be 180deg. from AC and represented by CE. If the loss in the motor is taken as 10 per cent. of its rating, which in this case equals 36kw., this is represented by CD, being in phase with the true power in the circuit. The total input to the synchronous motor will be equal to the vector sum of its leading wattless and power components CE and CD, that is $\sqrt{357^2 + 36^2}$ = 359kw., which represents the capacity of the synchronous motor required to raise the power factor from 0.7 to unity.

In this example the motor would simply be running light on the circuit without doing any mechanical work, and besides increasing the power factor to unity, it would reduce the load on the plant by 500 − (350 + 36) = 114kw.; so that its value would be = 500 − 114 = 386kw. It will be seen that the increase of 114kw. in the capacity of this plant has been gained at the expense of installing a synchronous motor having a capacity of 359kw., so that the capacity of the motor is very large compared with the increase in the capacity of the generating plant when the motor is not working on a mechanical load. The improvement in the operating conditions which takes place when the motor delivers mechanical power in addition to correcting the power factor, may be considered as follows, reference being made to Fig. 2:—Suppose the motor gives out mechanical power to the amount of 50kw. As this represents the true kw. input to the motor, it will be in phase with CD and represented by DF; then the total input to the motor will be $\sqrt{357^2 + 86^2}$ = 367kw. The increase in the capacity of the motor equals 2.23 per cent., and this will enable it to deliver 50kw. in the form of mechanical power, in addition to raising the power factor to unity. This example clearly shows the effect of making the synchronous motor convert part of its input into mechanical energy, and as the mechanical power delivered increases, the amount of power required for power factor correction will decrease.

The question of running a synchronous motor on a mechanical load may be further considered as follows:—Suppose a 500k.v.a. 3000-volt three-phase synchronous motor is operating at 70 per cent. of its rated capacity, and it is required to find the maximum load at 80 per cent. power factor that may be supplied from the system, so that the power-factor of the total load will be unity without

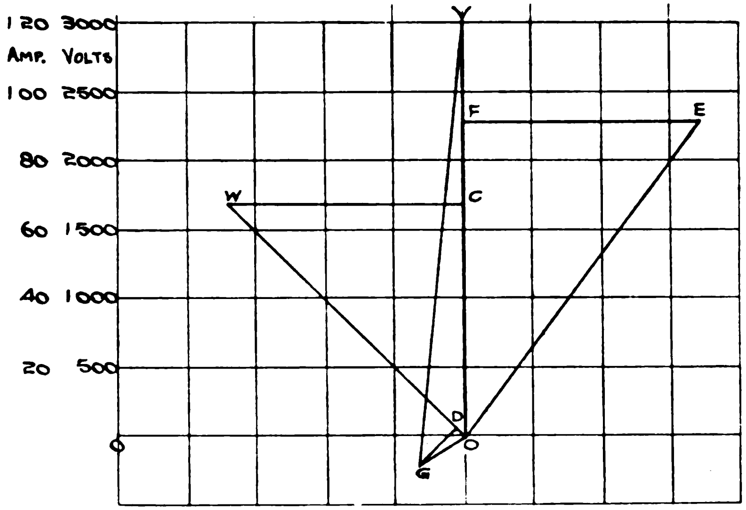


FIG. 3.

overloading the synchronous motor. Now the line current at the full-load rating of this motor $= \dfrac{500{,}000}{3000 \times \sqrt{3}} = 96.3$amp. per phase; but as the motor is only working at 70 per cent. of its capacity, the line current will be $96.3 \times .7 = 67.5$amp. Referring to the vector diagram in Fig. 3, let OV represent the impressed voltage 3000 volts, and OC the energy component of the current = 67.5amp. OW represents the total current input = 96.3amp., and CW the wattless component $= \sqrt{96.3^2 - 67.5^2} = 68.6$amp. As the power factor of the load is 80 per cent., this represents an angle of lag of about 37deg., having tan $\phi = .75$; therefore the energy component of the load current in the system $= \dfrac{68.5}{.75} = 91.5$amp., and as this component is in phase with the impressed voltage OV, it will be represented by OF. As the power factor is to be raised to unity, the wattless lagging component of the load current in the system will be equal in magnitude to the leading wattless component of the synchronous motor and separated therefrom by 180deg.; it will therefore be represented by FE = 68.6amp. The line current in the system is represented by OE, and is $\sqrt{91.5 + 68.6^2} = 114.3$amp; therefore the total inductive load =

$$\frac{114.3 \times 1.73 \times 3000}{1000}$$

= 593kw. (apparent).

It will, therefore, be seen that when the synchronous motor is operating at 70 per cent. power factor it will deliver a mechanical load of $500 \times .7 = 350$ real kw., and at the same time compensate for the lagging currents in the system due to an inductive load of $593 \times .8 = 474$ real kw. at a power factor of 80 per cent. without itself being overloaded. The counter e.m.f. of the synchronous motor at this load may be found as follows:—Suppose the armature resistance drop is 2 per cent. of the impressed voltage = 60 volts, then this may be represented by OD. Assuming the full-load reactance drop is 12 per cent. of the impressed voltage = 360 volts; this may be represented by DG, which is at right angles to OD, then the resultant OG of these two components will give the armature impedance drop = 365 volts. The resultant of the impressed voltage and the impedance drop which is given by VG represents the counter e.m.f. of the motor, which in this case scales 3230 volts: the motor should therefore be excited to give this voltage.

In the above examples we have considered the capacity of the synchronous motors required to raise the power factor of a system to unity, but as it rarely pays to raise it above 95 per cent., it will be of interest to consider a case where the power factor is to be raised to this value. Suppose the capacity of the plant is 500k.v.a. at 70 per cent. power factor, and that the synchronous motor is to develop mechanical power in addition to raising the power factor of the system to 95 per cent. These conditions may be represented graphically by the vector

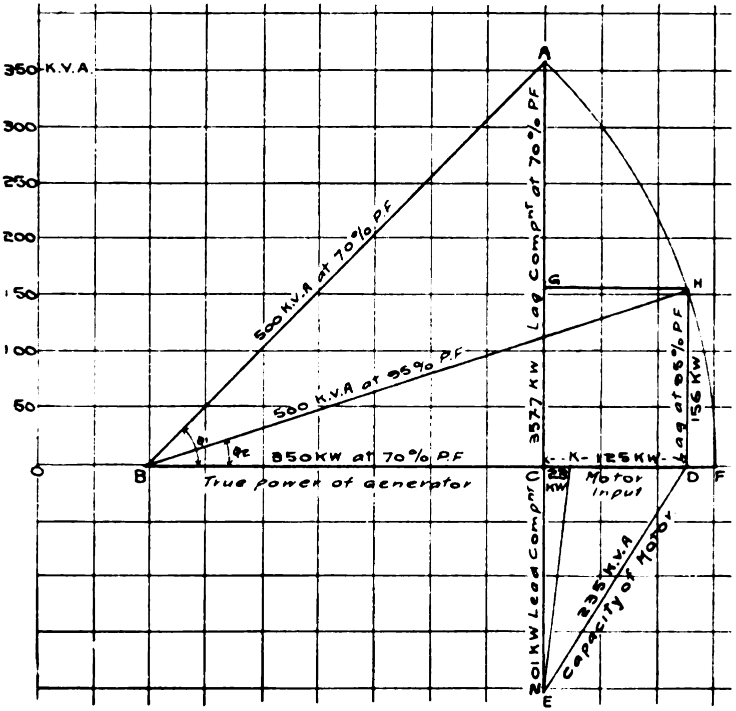


FIG. 4.

diagram in Fig. 4, which is constructed as follows:—Draw the current vector AB to represent the load of 500k.v.a. lagging behind the voltage vector BF by angle ϕ_1, the cosine of which is = .7. Make the part BC = 350kw. at 70 per cent. power factor, then the lagging wattless component, which is given by $\sqrt{500^2 - 350^2} = 357.7$, will be represented by AC. Next cut off the part BD to represent the true generator output, 475kw. at 95 per cent. power factor, then erect a perpendicular at D, making DH $= \sqrt{500^2 - 475^2} = 156$kw., the wattless lagging component in the circuit at that power factor. Draw HG parallel to CD, and join BH, which will represent the 500k.v.a. load in the circuit at 95 per cent. power factor, the angle of lag between the current and voltage vectors being then ϕ_2. Draw CE and make it equal to AG, then CE represents the wattless leading component in the motor which is shown by the scale to have a value of 201kw. The true input to the motor = BD − BC = 475 − 350 = 125kw.; then the capacity of the synchronous motor required is given by $\sqrt{201^2 + 125^2}$ = 236.6kw., which is represented by ED. Assuming the loss in the motor to be 10 per cent. of its capacity, this will amount to 23.6kw., and be represented by CK. It follows, therefore, that a synchronous motor having a capacity of 236k.v.a. is capable of raising the power factor of the circuit to 95 per cent., and at the same time will deliver mechanical power to the value of 125 − 23.6 = 101.4kw.

A comparison of these examples will show that the capacity of the motor required increases very rapidly as the power factor approaches unity. For instance, in the first example the capacity of the motor required to raise the power factor from .7 to unity without developing mechanical power was 359kw., but to raise the power factor of the same system to .95 and at the same time deliver 102kw. of mechanical power, requires a motor of only 236k.v.a. capacity. As the motor delivers 102kw. of mechanical power, the actual power consumed in correcting the power factor = 236 − 102 = 134kw. Supposing the capacity of this plant was increased to the same extent by installing a new generator, as this would require new steam plant, the total cost would be at least twice the cost of a synchronous motor having a capacity of 236k.v.a. The diagram in Fig. 4 has been used to work out the capacity of synchronous motors required to raise the power factor to various values on a 500k.v.a.

system having a power factor of 70 per cent. The results of these calculations are given in Table I., and are also represented by the curves in Fig. 5.

TABLE I.

Power Factor per cent.	Synchronous Motor.		Generator Load. K.V.A.
	Capacity in k.v.a.	Mechanical Output. KW.	
95	236	102	475
90	170	83	450
85	119	63	425
80	78	42	400
75	37.5	21.25	375

The curve A represents the capacity of the synchronous motor required to raise the power factor to different values, and shows that the capacity increases very rapidly as the power factor approaches unity. Curve B represents the maximum mechanical output delivered by the motor in addition to correcting the power factor.

Perhaps the following remarks on the construction of the diagram by means of which the above results were obtained, will simplify its use. A reference to the diagram will show that it consists of a series of triangles. One triangle represents the true output of the generator, inasmuch as its hypotenuse is proportional to the total k.v.a. in the circuit; its base represents the power component which is in phase with the impressed voltage of the system; the third side being proportional to the wattless component. A second triangle represents the input supplied to the load circuit, a third triangle representing the input to the synchronous motor, which is composed of the leading component supplied to the circuit for correcting the power factor and the mechanical output. The vectors representing the wattless leading component of the motor, and the wattless lagging component of the generator load, will be in direct opposition, and the wattless component of the generator load, after the power factor has been corrected, will be represented by the difference between these two components; that is to say, DH = CA − CE. A proper understanding of the above-mentioned principles will enable the capacity of a synchronous motor to suit any particular operating conditions to be easily determined.

The advantage of using a synchronous motor for increasing the capacity of the generating plant lies in the fact that it raises the power factor of the whole system, whereas the installation of more generating plant would introduce additional lagging

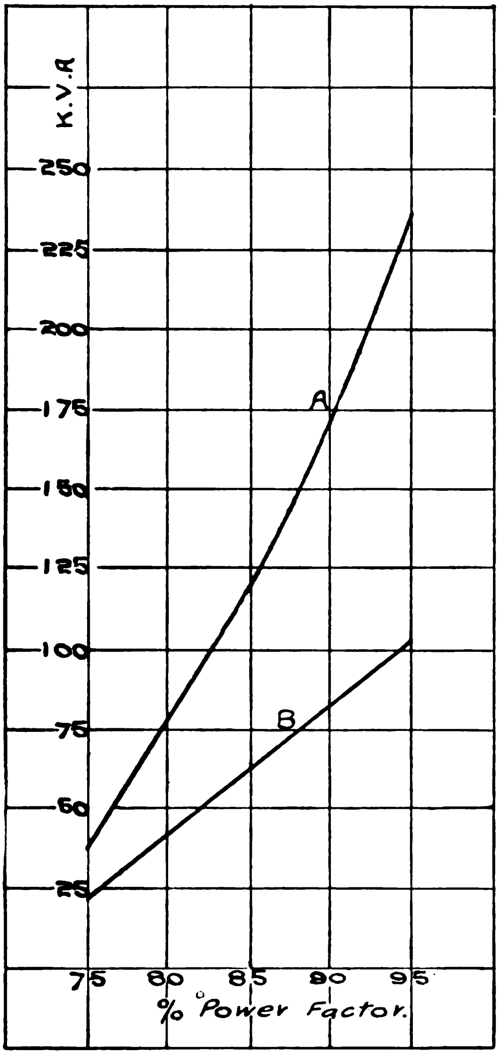


Fig. 5.

currents which would result in a further decrease in the power factor of the system. As will be readily understood, the capacity of synchronous motors is always rated in k.v.a. and not in kilowatts, as their output depends upon the power factor under which they operate. If the lagging currents in a system reduce the power factor to 70 per cent., the synchronous motor would have to operate with a leading current of the same power factor if that of the system is to be raised to unity, and assuming the load taken by the motor under these conditions is 500kw., then its rating would be $\frac{500}{.7} =$ 714k.v.a. A synchronous motor has also a tendency to improve the voltage regulation of a system besides correcting its power factor, and this question may be considered as follows:—Suppose the generator voltage is decreased due to a sudden increase in the wattless lagging currents in the system. This will necessitate an increase in the leading wattless current taken by the motor, which will in turn result in an increase in the generator voltage, owing to the fact that a leading current strengthens the generator field to a certain extent; the voltage drop will therefore be smaller than if no synchronous motor were connected to the system. For similar reasons a synchronous motor has a tendency to prevent the rise in voltage which takes place when an inductive load is suddenly decreased, so that the voltage regulation on the system is really improved. Against these advantages is the fact that the employment of the synchronous motor for compensating for the lagging currents in a system is a rather expensive method of correcting the power factor when there are no means of utilising the mechanical power of the motor. For this reason a rotary converter is more largely used for compensating purposes in present-day practice, and it has been found that a small increase in the weight of copper is sufficient to enable the converter to supply a leading wattless component equal to 50 per cent. of its k.v.a. rating in addition to supplying its full direct-current output.

In some cases synchronous motor generator sets are made use of for correcting the power factor, the capacity of the motor being increased to a small extent to enable it to supply the leading wattless component required by the system. Such a combination cannot, however, be compared to a rotary converter, so far as over-all efficiency and also synchronising power when overloaded are concerned, although a synchronous motor-generator set has a larger capacity for power factor correction than a rotary converter.

In conclusion, the question of a low power factor in systems supplying current to all classes of alternating-current machinery is one that calls for special attention on the part of station engineers, to whom the bad effects of a low power factor are only too well known.

J. W. ROGERS.

THE IRON, STEEL, AND ENGINEERING WORKS OF MESSRS. PALMERS' SHIPBUILDING AND IRON COMPANY, LTD.

LAST month the writer had the privilege, through the courtesy of Messrs. Palmers' Shipbuilding and Iron Company, Ltd., of describing in THE ELECTRICAL MAGAZINE the shipbuilding yards and auxiliary shops belonging to this firm, and at the close of that article intimated that at a future date he would return to this firm's activities, laying special emphasis on the electrical equipment which has been installed in order to deal with the production of iron and steel, and also to make reference to the modern and specialised plant which has been constructed to meet the growing needs for turbines in ship propulsion. A need for such a subdivision of the subject will be realised when it is remembered that Messrs. Palmers' undertaking is not an isolated manufacturing process forming a unit in the industrial interests of the community, but that it forms in itself the basis of existence of a large and densely populated town on the banks of the Tyne. The number of men in normal employment by the firm amounts to upwards of 6000, and as these to a large extent are congregated near to the gates of the shipyard and other works the town of Jarrow, whose population is approximately 40,000, may be said to subsist in either a direct or indirect manner upon the operations of this firm.

It has long been a principle with the company that as far as possible they should have in their own hands all the various manufacturing processes attendant on the building of a ship, and for this reason it was considered advisable, almost from the time when the first iron vessel was launched, to possess adequate means of manufacturing their own iron, and subsequently steel. It does not follow, however, because the reduction of ore by this company has been carried on for so many years that the plant it employs is obsolete—as a matter of fact in the pig-iron department the five blast furnaces are of a most modern description. They are all about 80ft. high by 11ft. diameter at the hearth, and vary from 19ft. to 23ft. diameter at the boshes. The product of these furnaces consists of Cleveland iron for foundry purposes and for the manufacture of basic steel and of high-class hematite iron, chiefly for conversion into mild steel by the open-hearth acid process. The output of Cleveland iron at present averages about 850 tons of pig-iron per furnace per week, while the hematite furnaces produce from 1000 to 1500 tons of pig per furnace per week. The general appearance of this section of the works is shown clearly in the illustration on page 305.

It is significant of the rapid progress which electrical engineering has made within the last few years that ten years ago in these steel works and blast furnaces there was no electrical equipment whatever for power purposes, whereas at the present date upwards of 1100h.p. in motors are installed. Formerly the pig-iron which was run out on to the cooling beds had to be broken by hand and loaded into wagons by manual labour. The improved means for handling the product includes an overhead electric gantry crane, made by Marshall, Fleming & Jack, of Motherwell, which traverses the beds for a distance of 400ft., and this crane, which will take a load of six tons, is capable of picking up a section of iron at any point under its 85ft. span, and transferring it to the table of an electrically-driven pig-breaker.

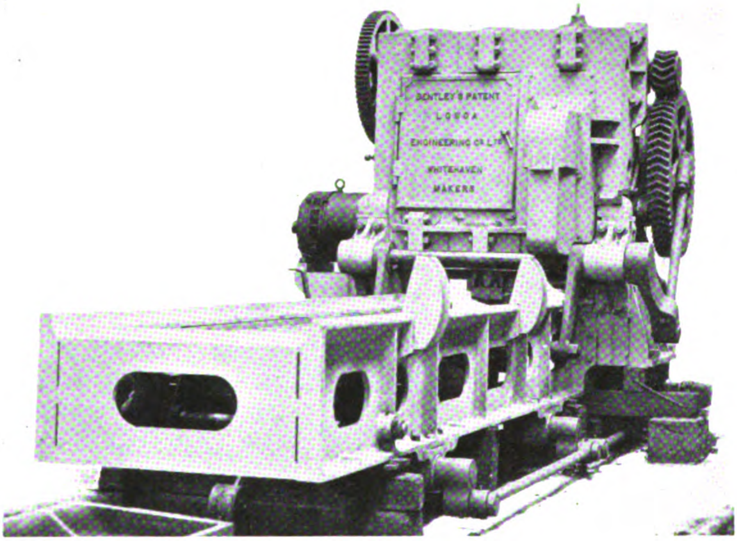


FIG. 1. PIG-BREAKING MACHINE.

The crane is of the three-motor type, the motors being made by Laurence, Scott & Co., Ltd.

The electrically-driven pig-breaker is arranged centrally along the length of the range of the furnaces to equalise the length of travel of the crane from either end of the beds. The illustration Fig. 1 shows the machine itself, which was constructed by the Lowca Engineering Company, Ltd., of Whitehaven: it is direct-driven through spur gearing by means of a 20h.p. Clarke-Chapman motor operating on a 480-volt continuous-current supply. As the "pigs" and "sow" are broken, the pieces fall down a shoot direct into wagons, and it is found that by means of this apparatus not only are fewer men required to break and load up the iron, but this is done more expeditiously, and inclement weather does not cause such a hindrance to these operations as was formerly the case when the breaking and loading were done by hand.

An interesting comparison is found in this plant between the old and new method of conveying raw material to the furnaces. At the older furnaces the coke, ore, and limestone are loaded by hand into barrows, which are then wheeled to vertical steam-driven hoists. These hoists convey them to the top of the furnaces, where they are tipped into the furnace hoppers by separate sets of men.

In the more modern plant, however, an arrangement patented jointly by Mr. Upton, the manager, and Mr. Prosser, the present engineer of this department, is employed. This is as follows. Adjacent to the furnace is a series of large storage tanks or bins about 40ft. high and capable of containing about 400 tons of coke, 1000 tons of limestone, and 4000 tons of ore. These tanks are carried on columns, clear of the ground, allowing ample light and ventilation underneath, and an extension of the columns also carries an overhead railway passing over the row of bins, and connected by an incline to the company's sidings. Thus ordinary mineral railway wagons are easily run by a locomotive to the top of any part of the bins, and the materials are then dropped through the bottom doors of the wagons into the tanks beneath, these being separated by internal partitions, so that different classes of ore can, if necessary, be kept separate. In the open space beneath the series of bins runs an electrically operated transfer car, on which is mounted, besides the receptacle for a definite charge of material, a weighing machine which registers at once the amount of material deposited in the car. The materials flow by gravity through the doors at the bottom of the bins, which doors control the operation. After it has been filled to the required amount the car is run along an overhead runway attached to the bottom of the bins and the material dropped into a skip which works on an inclined hoist, carrying the material to the top of the furnace. The trolley wires run alongside the runway, from which current is conducted to the motor of 5h.p. capacity which drives by means of spur gearing on to the travelling wheels of the car. With this plant only three men per shift are required for charging the furnaces with about 7000 tons of raw material per week. So satisfactory have these changes proved in this department that further alterations on similar lines are contemplated, as well as the electrification of the hoisting gears, pumps, and other auxiliaries of the blast-furnace plant.

The lighting of the blast furnaces department, which is entirely electrical, is obtained from an independent plant consisting of Alley & MacLellan enclosed high-speed engines driven from blast-furnace gas-fired boilers, and driving by means of belt on to Clarke-Chapman dynamos. In this independent power-house may also be found what is probably one of the first polyphase plants installed in this country. It consists of an Alley & MacLellan enclosed "Sentinel" engine of 150h.p., directly connected to a Clarke-Chapman two-phase alternator, the exciter being mounted on an extension of the shaft. This supplies various motors in the steel works driving continuous running machines such as in the roll turning shops, straightening and shearing machines, &c., an overhead transmission throughout the yard being adopted for this purpose. It is proposed at a later date to standardise the whole equipment in conformity with more modern practice, but due respect should be paid to this pioneer plant, on account of its utility in demonstrating at a very early date the value of alternating-current power transmission for industrial purposes.

The steel works are operated in conjunction with the blast furnaces for the purpose of converting the pig iron produced therein into mild steel, partly by means of the Siemens-Martin acid process and partly by Talbot continuous steel furnaces. In a convenient position adjacent to the working platform of the furnaces is installed a very completely equipped laboratory for the

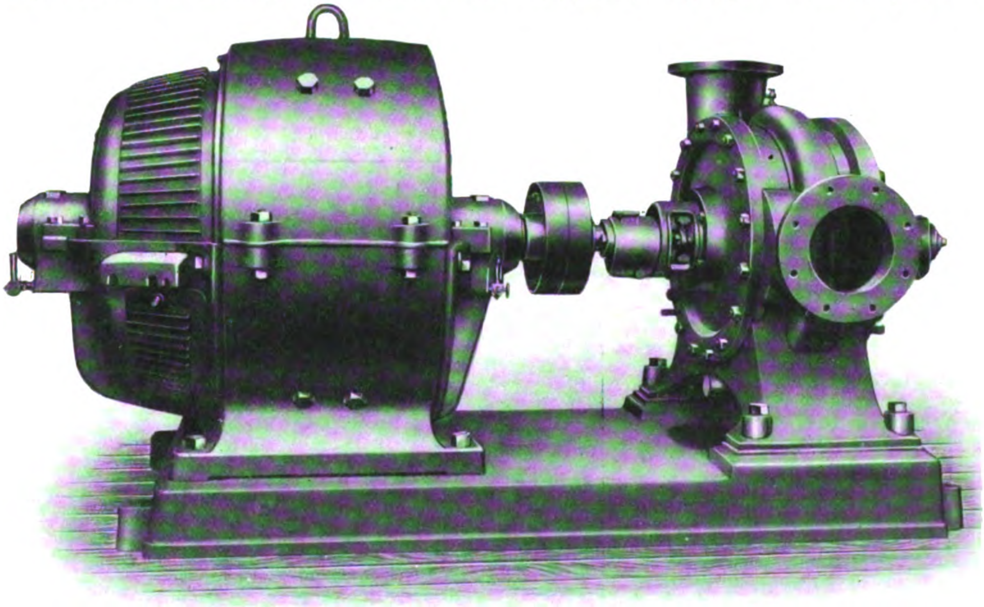


FIG. 2. ELECTRIC CENTRIFUGAL PUMP (SINGLE STAGE).

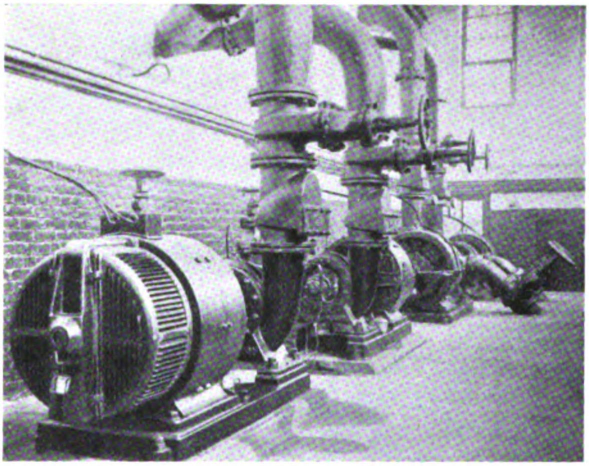


FIG. 3. FOUR LARGE CENTRIFUGAL PUMPS DIRECT COUPLED TO ELECTRIC MOTORS.

analytical testing of the material so as to ensure proper control of the process during the whole course of operations. The steel produced by both types of furnaces is tapped into ladles from which it is cast into ingots, and these are subsequently reheated preparatory to rolling into sheets and sectional material in the mills attached to this department. The two Siemens acid furnaces have hearths of about 24ft. by 11ft., and are capable of dealing with forty to fifty tons in each charge. They are of the gas-heated regenerative type, the waste heat of the furnaces heating brickwork chambers, which, on the reversal of flow of the gases, preheat the mixture of gas and air entering the furnace. Cold pig iron is charged on to the bottom of the furnace, together with about 20 per cent. of scrap steel, and after the charge is melted very pure hematite ore is added, oxidising the impurities in the iron and causing the molten metal to "boil" violently. At the end of the boil the metal is tapped into a ladle and the slag is then run off so as to completely empty the furnace ready for the next charge. In addition to this plant two Talbot furnaces for producing basic steel have been installed during the last year or two. The melting shop has been reorganised to facilitate their operation, and among developments contemplated in the immediate future may be mentioned the building of a mixer to serve these furnaces for the purpose of blending and partly purifying the metal before it is delivered to the furnaces.

Each Talbot furnace has a hearth about 37ft. long and 13ft. wide, with a capacity of 175 tons, and is capable of turning out approximately 1100 tons of steel per week; they work on the gas-heated regenerative principle and are built with the furnace-bodies supported on rockers, so that at any stage of the process they can be tilted by hydraulic cylinders to either side.

The charge for the Talbot furnace consists chiefly of pig-iron in the molten state, brought in ladles directly from the blast-furnaces, or from a mixer, and poured in the furnace. This iron having been worked down by the addition of ore or scale and lime till the furnace contains its full quantity of purified steel, about one-third of it is tapped off and cast into ingots, then a corresponding quantity of

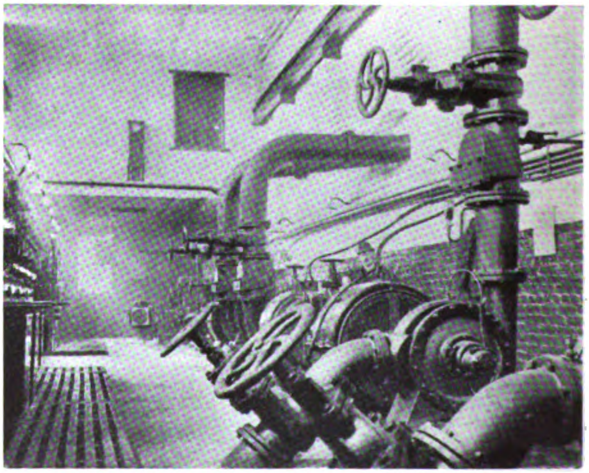


FIG. 4. VIEW OF PUMP HOUSE AND SUBSTATION PLANT.

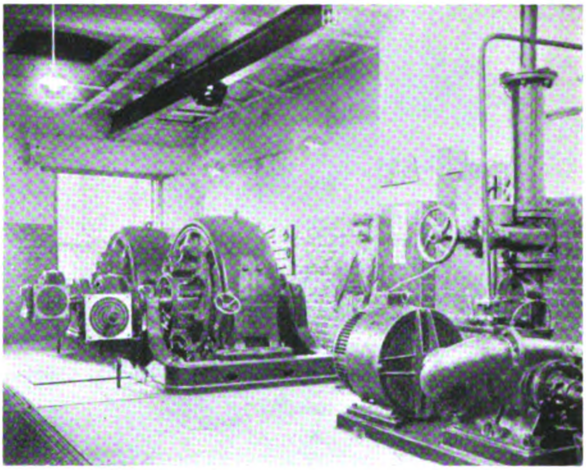


FIG. 6. VIEW OF SUBSTATION PLANT.

molten pig-iron is again charged and the whole worked down into steel, so that the process goes on continuously with alternate charging of pig-iron and tapping off steel, slag being drawn off at intervals from the opposite side of the furnace from which the steel is tapped, but the furnace never being less than two-thirds full of steel except at week-ends. As a large amount of heat is developed by the chemical reactions which occur in working the Talbot process, a complete system of cooling by water circulation is adopted for the furnace charging doors, chills and other parts most liable to be injured by the intense heat. For this purpose a well-arranged system of electrically-driven pumps, with the necessary storage tanks, &c., is installed in a convenient position near the furnaces. There are two storage tanks, of about 13,000 gallons capacity each, built round and supported by the furnace chimneys, at a height of 55ft. above the charging platform, and from these the water is distributed to the various parts of the furnaces requiring to be cooled. A single-stage centrifugal pump, driven by a motor of 55b.p.h. (Fig. 2), lifts the water into the storage tanks, delivering 1250 gallons per minute against a vertical head of 98ft. After use at the furnaces the water is collected and returned for cooling to the reservoirs by a 30h.p. electric centrifugal pump. Inasmuch as the furnaces are in continuous operation, the failure of cooling water, even for a short time, would involve the stoppage of work and possibly serious damage to the furnaces; the pumps and motors have been installed in duplicate, so that in case of stoppage, either of the stand-by sets can be put into operation in the course of a very few minutes. Adjoining the plant are two smaller pumps, also electrically driven. One of them is a centrifugal pump driven by a 12h.p. motor for lifting the rain water, &c., which is collected in a large culvert underneath the foundations of the furnaces, delivering it to the return water pumps above mentioned for discharge into the works reservoirs. The other is a small ram pump driven by belt from a 5h.p. motor, and it works in conjunction with a hydraulic accumulator for use at week-ends when the main hydraulic pumps are not in use.

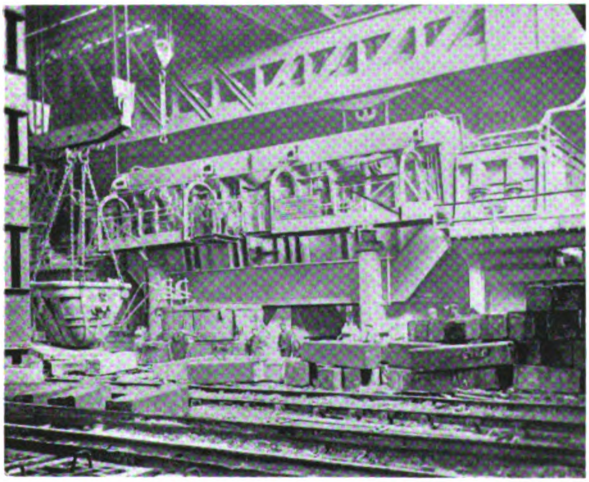


FIG. 5. TALBOT FURNACES.

The five centrifugal pumps are all of the Worthington type, and are

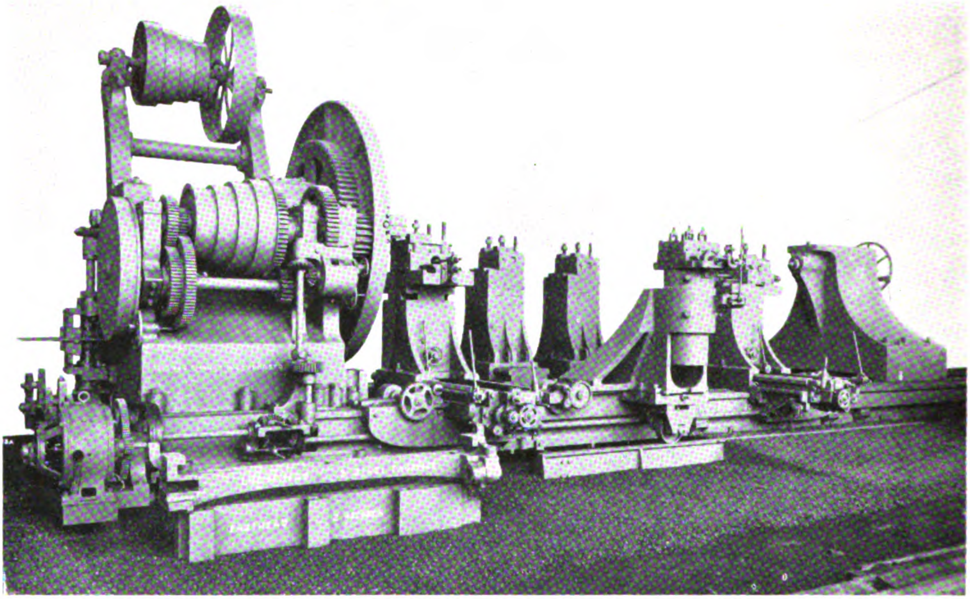


Fig. 7. Quadruple-geared Double-bed Lathe

direct driven through flexible couplings from the motors. The hydraulic ram pump was supplied by Henry Berry & Co., of Leeds. The six motors were all constructed by Messrs. J. H. Holmes & Co., and are of the totally enclosed shunt-wound type. Fig. 3 is a view of the pump house showing the four larger centrifugal pumps and motors. These are operated by means of Reyrolle drum type starters, while the two smaller ones are controlled by automatic starters, the one actuated by a float in the drain culvert, and the other by the ram of the hydraulic accumulator. The whole of this pumping plant, together with the necessary switchgear, starting panels, &c., is accommodated in a substantial brick building, an extension of which forms a substation for the main supply of electric power and lighting to this part of the works, and which will be referred to later. Fig. 4 shows a view of the pump house with the substations in the background.

The ore and lime or other solid materials required for working the Talbot process are charged into the furnace by a three-ton open-hearth charging machine, which was constructed by Messrs. Wellman, Seaver & Head, Ltd. This machine runs on a track laid on the charging-stage, and is operated by four Westinghouse direct-current motors with B.T.H. tramway-type controllers. The charging platform is commanded by two powerful five-motor electric overhead ladle cranes, one of which was made by Messrs. Marshall, Fleming & Jack, and the other by Messrs. Booth Bros., the motors for both being supplied by Messrs. Laurence, Scott & Co., Ltd., of Norwich. As one of the principal duties of these cranes is the rapid handling of ladles of molten metal, and as, moreover, any stoppage or breakdown would cause serious delay in the working of the process, they had to comply with a very stringent specification. Each crane is of 62ft. span, with 46ft. clear lift, and has two independent crabs, the heavy one running on the top of the main crane girders, and being capable of handling a load of 60 tons, while the auxiliary crab, which travels between the main girders on a path carried by their bottom flanges, can deal with loads up to 15 tons. The whole framework of the cranes and of the crabs is composed of rolled steel strongly braced and gusseted to ensure rigidity. The main girders are of box section, with strong cross and diagonal bracing between them along the top to give side stiffness and prevent spreading under the load. To secure uniform distribution of weight, each crane is carried by four swivel travelling carriages, each running on two wheels on the main track, all the bearings being of the self-oiling type. A strong shaft, driven by means of a motor situated in the centre of the span, is carried by an outrigger girder across the crane, and is connected by spur gearing to one of the travelling carriages at each end of the crane to prevent cross winding.

The main crab, which supports the ladle of molten metal while it is being tilted by the smaller crab, is furnished with two separate hoisting barrels from which two sets of steel-wire hoisting ropes are led down on the outside of the main girders to support the ladle crosshead. The ropes at each end of the crosshead are in duplicate, so that in case of one breaking, the other would still carry the ladle in safety, and special provision is made to ensure each strand of both ropes taking its proper share of the load.

On both crabs the hoisting gear is fitted with automatic electric and auto-mechanical self-sustaining brakes, and an automatic cut-out is provided in each case to prevent overwinding. The cross traverse motions are fitted with auto-electric brakes, while the longitudinal travel is controlled from the driver's cage by a powerful foot-brake. The working speeds with full loads of 60 and 15 tons are:

Hoisting, $7\frac{1}{2}$ft. and 30ft. per minute respectively.
Cross traverse, 50ft. and 100ft. per minute respectively.
Longitudinal travel, 250ft. per minute respectively.

The whole of the gearing of the cranes is machine cut, the first motion in each case being run in an oil bath, to secure highest efficiency. All the bearings have ample surface, and care has been taken to provide proper lubrication. Convenience of access for inspection or adjustment has been specially considered, and the arrangement of the cranes is such that any shaft can be lifted out without any other shaft or any gear having to be removed.

The motors are of the series-wound totally enclosed crane type, running at slow speeds so as to minimise the quantity of gearing required, and they are operated B.T.H. con-

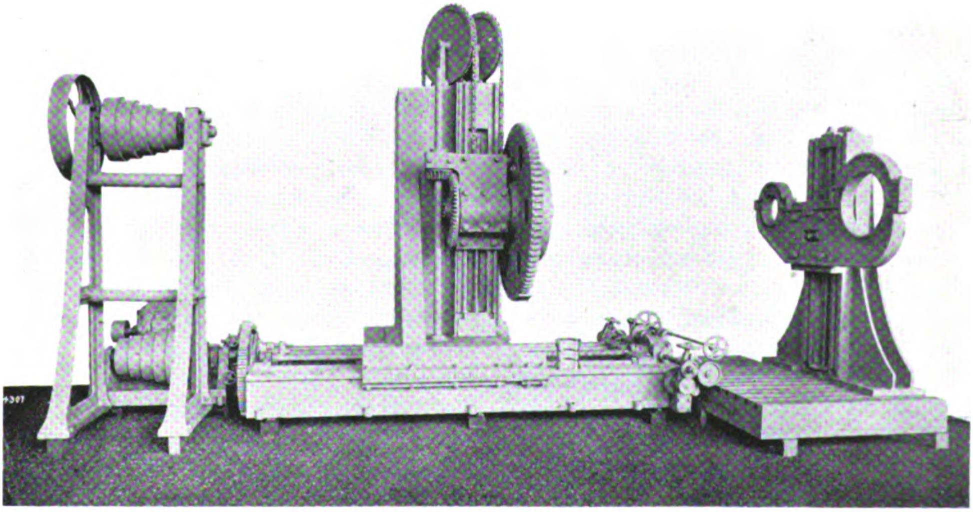


FIG. 8. BORING MACHINE FOR STEAM TURBINE CASINGS.

trollers. The electrical equipment is of the highest class throughout and is specially arranged for convenience of operation. A main or emergency switch and cut-out controls the supply of current to the crane, while fuses and circuit breakers are fitted to all the motor circuits, and the wiring is run in conduits wherever possible to protect the insulation from mechanical damage. The driver's cage is suspended under the outrigger girder in such a position as to give the best possible view of the work in all positions, and to protect the driver and the controllers and instruments from injury from heat or fire.

The tapping side of the Talbot furnaces, shown in Fig. 5, is commanded by another pair of five-motor electric overhead ladle cranes of 48ft. span, each having two separate crabs capable of dealing with loads up to 35 tons and 12½ tons, the working speeds of these being:

Hoisting, 10ft. and 40ft. per minute respectively.
Cross traversing, 100ft. per minute.
Longitudinal travelling, 300ft. per minute.

Their principal duties are to handle the ladles of slag and occasionally metal from the furnaces and to strip and remove the steel ingots from the casting pits. They were both made by Messrs. Booth Bros., Ltd., of Rodley, and are designed on precisely similar lines to those at the charging side of the furnaces, the gearing, motors, controllers and other parts being interchangeable as far as possible on all the cranes. After the steel has been run into ingot moulds and taken their shape, it is transferred into gas heated regenerative vertical furnaces by steam jib cranes. The lids of the furnaces are lifted by means of an electrically-driven carriage, operated by a single motor drive from the direct current supply, by an overhead trolley pole making contact with bare copper conductors running the length of the furnaces.

After heating, the ingots are drawn from the furnaces by a single-motor "Goliath" crane, which was originally steam driven and converted to electrical power operation by the firm, and the capacity of which ranges up to 5 tons. This crane places the ingots on a special car, attached to an endless rope haulage, by which it is conveyed to the mill, where the ingot is automatically transferred to the mill feed rollers.

At the present time the mills which roll the ingots into various sections are steam-driven, but a considerable amount of auxiliary machinery, such as the shearing machines for cutting sections of the steel into short lengths, the saws, skid gears, live roller tables, &c., are either already electrified or consideration is being given to the installation of a motor drive in connection with a scheme which the company have in hand for the reorganisation of the power system.

It may be advisable at this point to draw attention to the main method of obtaining power and lighting supply for this department. A substation has been installed closely adjacent to the steel furnaces, in an extension of the pump-house already described, its situation in a central position with regard to the demand for power and light for the steel works making it a convenient distribution centre for these circuits. To this station power is supplied by means of three-phase current at a pressure of 5500 volts, 40 periods per second, from the power mains of the County of Durham Electrical Power Distribution Company, Ltd. The high-tension mains are brought in duplicate to an overhead chamber containing two static transformers made by the British Westinghouse Electric and Manufacturing Company, Ltd. These transformers, which are controlled by Reyrolle high-tension switchgear, convert the supply to a pressure of 440 volts between phases. It is then taken to the portion of the substation under the care of Messrs. Palmers' Shipbuilding and Iron Company, Ltd., in which two Westinghouse rotary converters, each of 350kw. capacity, and shown in Fig. 6, are used to give direct current at 480 volts for power and 240 volts for lighting on a three-wire system which extends throughout the department. Mid-wire balancers installed on extensions of the converter shafts serve to equalise the pressure on the two sides of the system and switchboard.

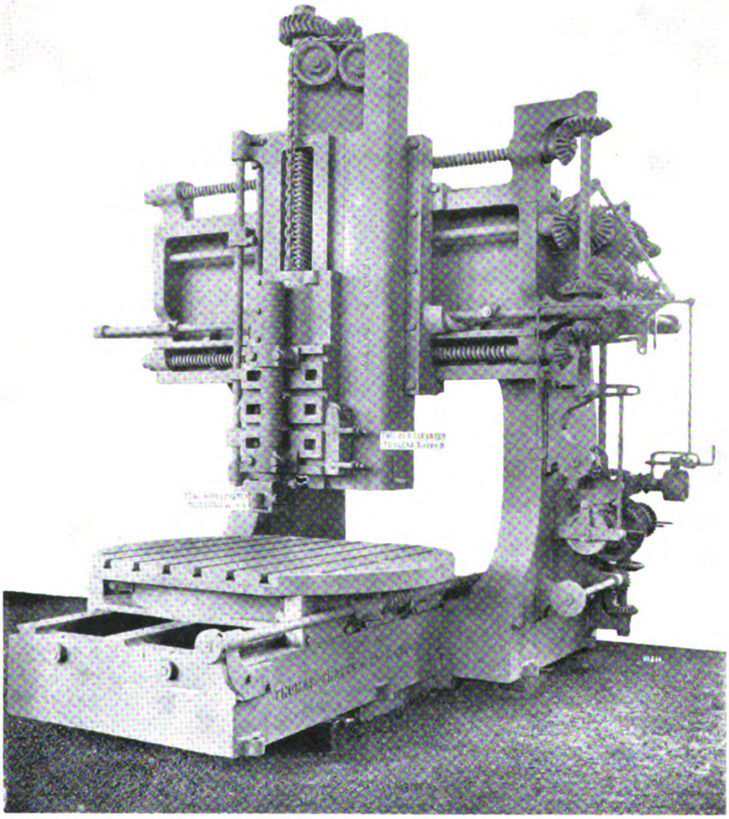


Fig. 9. Heavy Vertical Slotting Machine.

Two Westinghouse starting panels control the operation of the rotary converters, while the continuous current is led from the machines to a Reyrolle switchboard provided with all the necessary controlling and regulating apparatus. This board is also fitted with automatic time switch and maximum demand indicators, and Chamberlain and Hookham meters are installed to register the total power consumption. Accommodation is provided for a three-phase distribution board should the company decide to apply 440-volt a.c. motors for driving any machinery in the steel works. One end of the switchboard for the pumps already mentioned is reserved for the control of the direct-current power circuits, space being provided for future extensions. All these circuits are protected with fuses and circuit-breakers, the latter being fitted with special loud-ringing gong attachments, so that if any circuit is opened the attendant's attention is immediately drawn to it in whatever part of the station he may happen to be. At the opposite end of the board it is intended to fit up panels to control the circuits for the electric lighting of the whole department, which will be fed from the transformer and rotary converter equipment. Electric lighting has been used here from a very early period, this form of illumination having gradually extended until it forms at present almost the only source of light available for the steel works.

The building of the substation, however, offers a favourable opportunity to have this reorganised on standard lines, which will very much simplify the arrangements and largely increase its efficiency. The turbo-generators, which have been in use for lighting purposes up to the present time, were among the earliest installations on the Parsons principle, which has been developed to such an amazing extent, especially within the last few years; and a very interesting comparison might be made between one of the huge turbines propelling the vast structure of a *Mauretania* across the ocean, and its tiny forerunner of these early days.

The coal-handling plant in connection with the range of steam boilers for the steel works is also electrically driven. The coal wagons are fed by a gravity siding arrangement to a hoist, which elevates them, one at a time, to the top of a line of hoppers extending along the front of the boilers. The wagons are pulled along the railway on the top of these hoppers by means of an endless rope haulage, and arrangements are made to discharge the coal through the bottom doors of the wagons into the hopper for any particular boiler required, after which the empty wagons are returned to the ground level and run off by another inclined siding. From the hoppers the coal descends by gravity into the feed boxes of Bennis mechanical stokers, which are installed on each boiler. An overhead runway attached to the bottom of the hoppers forms a very expeditious and satisfactory method of ash disposal, and the whole arrangement, which has been designed by the firm, is in every way superior to the old style, in which manual labour was employed. It may be mentioned that there is a complete installation of economisers, feed-water heaters, and induced-draught plant, in connection with the boilers, which are supplied with feed water from a large central condensing plant operated in connection with the large steam engines driving the rolling mills in the steel works.

The rolling mills consist of a 38in. slab cogging mill, a 36in. cogging mill for sectional blooms, and a 36in. roughing and finishing mill (together with the usual equipment of roller gear, saw racks, hot saws, skid gear, hot banks, &c.), for finished bars, a 12in. merchant mill, for the smaller sections, and a 24in. sheet mill, the principal product of which is sheets for torpedo boats and the like. In addition to this the department carries on an extensive business in electro-galvanising

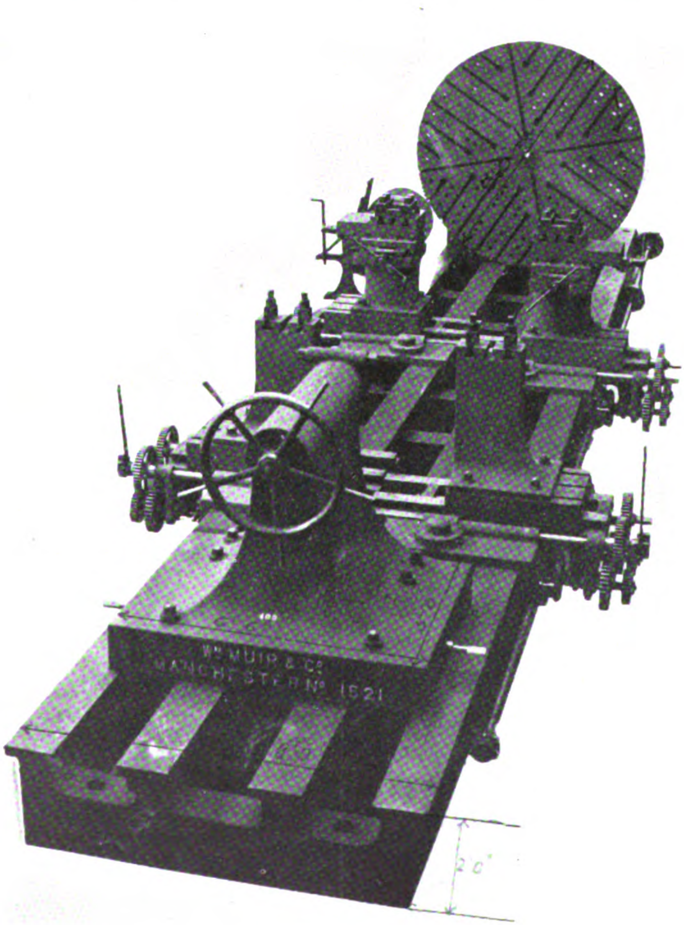


FIG. 10. LATHE, 54IN. CENTRE, 48FT. BED.

and hot galvanising and also in the kneeing and cambering of deck beams for ships.

Up to the present we have been dealing with what may be termed the raw material, both of the shipbuilding and engine-works departments of the firm. In the previous article was described to some extent the way in which electricity is employed in the construction of ships of all classes by this firm, but the writer was unable to give any adequate idea of the department by which these boats could, when launched in the Tyne, be equipped on the spot with a complete set of engines and boilers, so that it would be possible for such a boat to take to sea without passing through any other hands than that of the various departments of Messrs. Palmers, which work so harmoniously together. The productive capacity of the engine works may be gauged from the fact that in one year thirty-four sets of engines and boilers were turned out, and the work in this section ranges from the building of high-speed machinery for torpedo-boat destroyers, to the massive engines and turbines required on a first-class battleship, as well as the supply of means of propulsion for every class of ship in the mercantile marine.

It will be impossible to detail in full length the uses to which electricity has been put in these departments. The chief point of interest in this section is the new erecting shop, which has recently been constructed for the purpose of meeting the demand for turbine propulsion. Messrs. Palmers' Shipbuilding and Iron Company, Ltd., have entered into an agreement with Messrs. Parsons' Marine Steam Turbine Company, Ltd., whereby they have acquired the right to manufacture turbines of the largest capacity for the purpose of ship propulsion, and a new bay has been added to their erecting shop, measuring 400ft. long by 59ft. wide. This is dominated by three cranes, two having a lifting capacity of 40 tons and one of 20 tons; the cranes were built by Messrs. Craven Brothers, Ltd., one motion on each crane driving all the motions and the light and heavy lifts by means of belts. The erecting shop has been designed so as to undertake work of a size equivalent to the largest capacity of battleship it is at present conceivable will be designed, and provision is also made for the turning out of reciprocating engines when these are required. At one end of this bay are two specially fine machine tools, which are so representative of modern practice that it is necessary to refer to them in some detail.

These are a lathe and boring machine supplied by Messrs. Shanks & Co. The lathe, which is of the heavy quadruple geared double-bed type, includes a double-slide bed of very great width, of special section to resist the strain of heavy work of large diameter. Inasmuch as owing to difficulties in transport the slide bed is in two widths, the front bed is cast in one with the slide which takes the upward lift of the back rests, this slide being brought as near the centre as possible. Cross ribs cast at the bottom secure further rigidity, and each bed has a guide screw resting on the bars with a very long disengaging nut on the saddle. A gear for hand and power traverse is also provided. The base of the fast and loose headstocks across the bed is very wide, allowing very heavy cuts to be taken, while the saddles and slide-rests in connection with the loose headstock are so designed that very short diameters, and exceptionally short work, can be placed between the centres. The gearing includes Barrows' patent for quadruple, treble and single purchase, and has five reductions, exclusive of the countershaft. It is driven by means of a 60h.p. Westinghouse motor placed at the back of the lathe, which runs at either 425r.p.m. or 570r.p.m., this motor being specially wound with two windings in order to give this variation in speed. The motor is started by means of an auto starter, and a special switch is arranged to throw over from one set of windings to the other as required. The loose headstock of the lathe has an adjustment to secure perfectly parallel sliding, and is also moved by power. The saddles with the disengaging nuts are specially constructed for heavy strains, and are very deep, this being further increased by the recess in the bed. The back and front saddles, which in this case are two in number, are connected independently from the fast headstock for sliding and boring through the guide screws and change-wheel systems without altering the swing frame, each saddle at the front being fitted with a self-acting surface rest and swivel rest, the insetting slide being worked by hand. Each saddle at the back has a self-acting surface rest and fixed compound rest specially made to resist upward strains. In order to make this lathe suitable for tipping the rotors of turbines as well as for heavy general marine work, it has been fitted with Barrows' patent additional details. By adding the height of the centres, which is taken from the outer sides of the bed to the recess in the middle and doubling it, the diameter of a low-pressure rotor with the blades on is obtained, and dealt with by the patented details. This diameter would probably do the greater portion of the firm's work, and by use of a moderate packing an increase is made for the largest rotors likely to be made. This special packing for both fast and loose headstocks can be shipped and unshipped in a few hours, and does not increase their transverse width. A cast-iron girder is fixed into the ground about ½in. above the foundation, and planed true with the front bed at some distance upward. This girder, when not in use, is covered with a board. A very strong saddle is fitted on this bed to produce the same accurate sliding as on ordinary rests, and is provided with disengaging nut, independent guide screw, swing frame bracket and change wheels for varying the self-acting motion, in either direction, to as fine limits as may be desired, the overhanging pressure being taken by the true surface of the girder through an adjustable roller wheel. A special column is firmly bolted to the saddle at any distance to or from the centre within reasonable limits, which column is bored vertically to admit a strong circular stem fitted with insetting slide rests for the tools adjustable to the height of any packing which may be used. This leaves the ordinary saddles and rests independent.

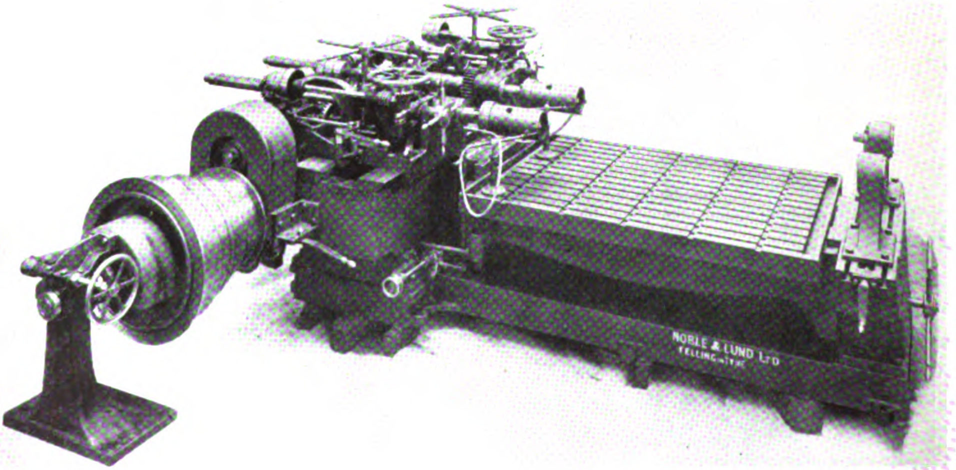


Fig. 11. Duplex Horizontal Drilling, Tapping and Boring Machine.

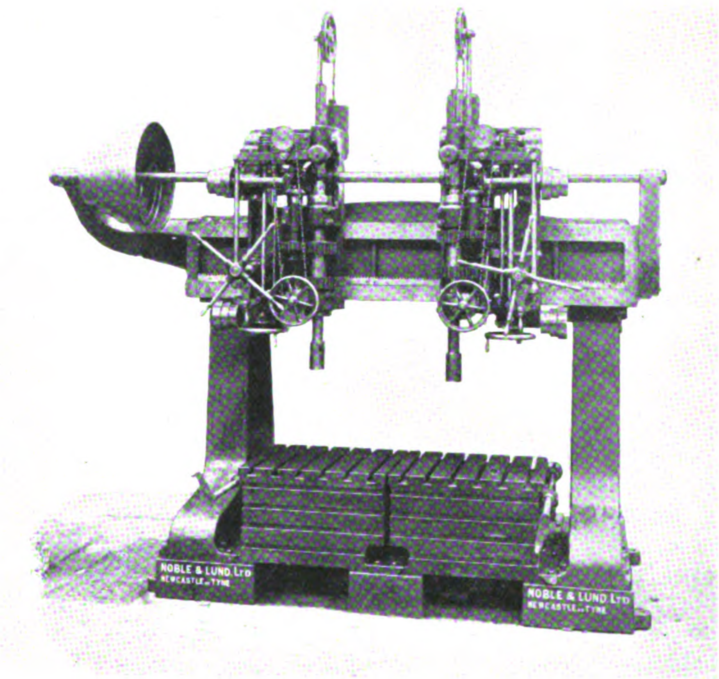


FIG. 12. DUPLEX VERTICAL DRILLING AND TAPPING MACHINE.

Very strong cast-iron packings are also provided for the fast headstock, which are bolted to the bed and require no adjustment for truth. There are also strong steel casting traverse packing for the loose headstock, which require no adjustment and do not increase the width, and which, moreover, make it as free to move along the bed as before. In order to secure this power movement a 15b.h.p. Westinghouse motor running at 570r.p.m. operates on the gearing for the head and saddles. This is shown in Fig. 7, illustrating this most interesting lathe, which is 25ft. between centres and has a 17ft. 6in. swing.

Of almost equal interest is the boring machine, made by the same firm for the purpose of boring steam turbine casings after they have been fitted together. They rest upon the base plates of the machine in the same position that they afterwards take as they lie in the ship, the machine performing the work accurately round and parallel. This machine consists broadly of a wide slide bed with two driving shafts, having at the middle a guide screw. At the end is fixed a self-contained stock with a cone pulley, and three complete systems of machine cut gear. Upon the bed and sliding upon it is fixed a strong standard with quick power reversing speed and two independent systems of variable feed, one on each side of the bed with a swing frame. The set of change wheels, shown in Fig 8, illustrating the boring machine, is common to both. Upon the standard is fitted a special patent driving headstock saddle, containing two independent systems, one for rotating the bar for quick speed through bevel and spur gearing, with a solid disc spindle, and the other through a machine-cut worm gear and tubular spindle, with special detail for eliminating friction. Both these systems are connected to a strong three-jaw chuck, which firmly grips the boring bar; the headstock is balanced and has hand vertical adjustment to obtain the exact height from the work-plate required. This plate is firmly attached to the bed and made as true as possible, and long and wide enough to allow the casing to be bolted thereon. The stays at each end are planed with tee grooves from the solid. Two very strong standards, which have cast-steel stays, adjustable vertically, are fitted with caps so that the boring bars are dropped into place. Two sizes of holes are bored in these stays, suitable to either small or large diameter bars. The boring machine is fitted with Barrows'

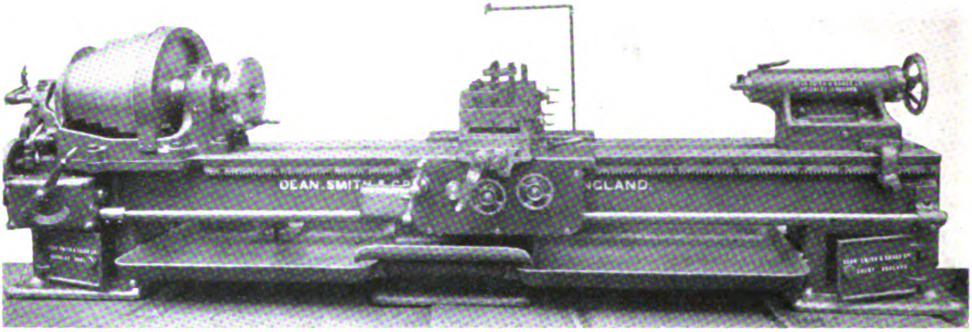


FIG. 13. LARGE SELF-ACTING LATHE.

patent differential boring bars for turbine casings. It is well known that a 12in. boring bar is insufficiently strong to bore the largest marine cylinder, and that turbine casings are double the diameter and five times the length of a cylinder. Moreover, a solid 12in. bar 40ft. long, weighing about seven tons, is as heavy as a hollow 17in. bar having more than double its tortional value, the deflection in a hollow bar being enormously less. Hence by the use of Barrows' patent bars absolutely true and concentric boring can be obtained. The boring machine has a bed of 50ft. long by 20ft. wide and is driven by means of a Westinghouse motor running at 570r.p.m. with a belt drive as shown in the illustration.

Adjacent to, and parallel with, the new erecting shop just described, is the fitting shop devoted to the same class of engineering. It is nearly the same length as the erecting shop, and contains, besides the usual complement of fitters' benches, a group of radial drillers which has a rather interesting drive by means of a shaft, belt-driven from a motor mounted on one of the columns. This motor, which is of 30b.h.p., is specially constructed as regards oil wells, baseplate, &c., so as to be mounted directly on the vertical face of the column. The shop is dominated by three cranes, all of which are electrically-driven: an exceedingly light and efficient type being one by Messrs. Marshall, Fleming & Jack, which is of the girder type, giving by its light lattice construction the maximum strength with the requisite lightness for quick-speed work.

It is impossible, of course, to draw a hard and fast line as regards arrangement between the fitting and machining departments, and in this bay are to be found a large boring machine made by Messrs. Smith, Peacock, & Tannett, capable of work up to 100in. diameter, and separately belt-driven from a 10h.p. motor, together with two wall planers by Messrs. Hulse & Co., of Manchester, capable of taking work up to 20ft. by 18ft. The latter, together with other machine tools, are driven from a main shaft by means of a 30h.p. motor.

The heavy machine shop and the medium machine shop are completely equipped with a series of tools, which could not be described in detail in an article of these dimensions, but of which representative types may be taken. A very powerful vertical slotting machine, illustrated in Fig. 9, has been supplied by Messrs. Thomas Shanks & Co., and constitutes one of the most modern tools of this nature. The bed is 14ft. long, and the opening in the frame for work is 7ft. wide and 3ft. 8in. high. The diameter of work which can be slotted in the middle is 10ft. The work table is 8ft. in diameter, with the slides flattened to 6½ft. A balanced cast-steel tool slide is driven by means of a screw with thrust bearings and gearing, and has a slotting stroke of two speeds up to 6ft., with a planing movement of one speed up to 7ft.

It is capable of slotting or planing 6ft. in width and the adjustment of the vertical bed is 3ft. The fast and loose pulleys are suitable for belts 6in. wide, and the machine is driven by means of fast and loose pulleys off a countershaft drive. This combined slotting and planing machine built under Barrows' patent is extremely useful for the heavy forgings machined by Messrs. Palmers', such as solid or built-up cranks, stern posts or connecting rods, and is used for slotting the keyways for such work as propellers. A cross planing motion of the machine dispenses with the necessity for a transverse slide and overhanging work can be supported so as to be slotted or grooved at different positions. Internal grooves can also be slotted in work which when rotated would not otherwise clear the uprights, and the resetting of work is in many cases eliminated. It will therefore be seen that the machine is representative of the most up-to-date practice.

Another interesting machine in this department is a large lathe made by Messrs. Muir & Co., Ltd., and shown in Fig. 10. This machine has 54in. centres with a bed 48ft. long, and will take work up to 32ft. long between the centres. The diameter of the largest cone is 3ft. and the front neck of the spindle is 18in. in diameter and 2ft. long. The headstock gear is arranged to work in double, treble or quadruple gearings, and four carriages are fitted, each having a self-acting motion along the bed.

There are four independent tool slides, each self-acting by screw and bevel gear, with clutches for engaging and disengaging the tools. Two of these slides are arranged for turning pins, &c., and two for compound rests for turning shafting, all the slides being interchangeable on the carriages. This machine has been in daily use for a considerable number of years, and has proved itself to be one of the most reliable heavy lathes which could have been obtained. Among other heavy machines in this shop may be mentioned the large planing machines by Messrs. Hulse & Co., and other makers.

The work in the medium machine shop is transported to position by means of either of two cranes of very light and powerful type, one being by Messrs. Marshall, Fleming & Jack, of generally similar description to the one mentioned above. Among the machine tools in this section may be mentioned some useful horizontal and vertical drilling, tapping and boring machines of the duplex type, made by Messrs. Noble & Lund, and shown in Figs. 11 and 12.

With regard to the vertical machine, a strong cross slide is carried on the top of two cast-iron columns and is fitted with two drilling heads, each having a steel spindle 3in. in diameter with a self-acting or hand vertical traverse of 18in. These spindles are balanced, and are capable of being raised or

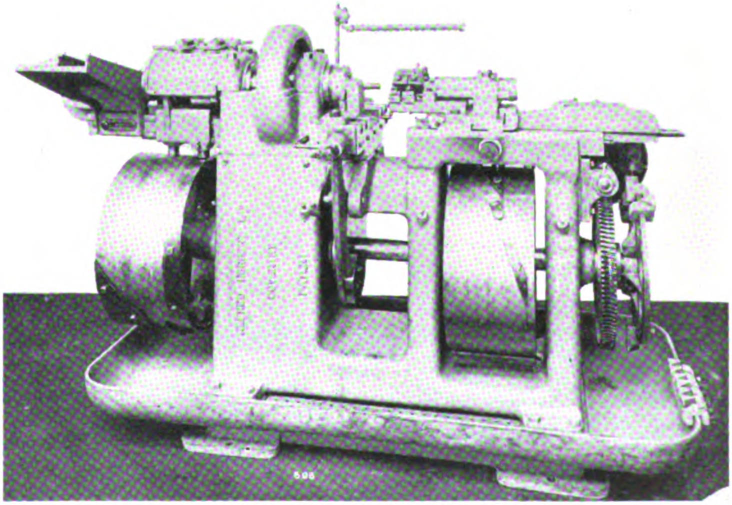


Fig. 14. Automatic Stud Machine.

lowered quickly in addition to the ordinary slow hand motion. A range of eight speeds is obtainable by means of a four-speed cone and change gear on each saddle, the speed ranging from 20 to 150 revolutions, with a countershaft speed of 160r.p.m. Either spindle can be started, stopped or reversed independently of the other. The tables are each 3ft. 1in. wide by 3ft. long on the top, and about 2ft. deep, having planed tee slots on the top and front side. They are separately movable in or out by worm or wheel, or rack and pinion, and if necessary, they can be moved together, forming one complete table. The distance between the columns is 7ft. 3in., and the distance between the spindles ranges from 9in. to 6ft. 3in. The horizontal machine is of the same general type, with constructional differences which can be seen from the illustration.

Among the lathes in this department are several of exceptional power constructed by Messrs. Dean, Smith, Grace, Ltd., and a typical lathe is shown in Fig. 13, designed for high-speed work with the latest class of tool steel. It has 16in. centres, the driving cone being 34in. diameter on the top speed, driving a 6¼in. belt. The bed is 2ft. 6in. wide over the vees and 1ft. 6in. deep, being of large proportions in the slide and wearing surfaces The front bearing of the fast headstock is 9in. diameter by 12in. long, and the drive is through a five-speed cone pulley, varying from 12in. to 34in. diameter, the gearing giving a ratio of 13.8 to 1. A uniform range of speeds suitable for all classes of work has been obtained by correct grading of the cone and gearing, ranging from 5.04r.p.m. to 14.13r.p.m. with the gear, and from 70.05r.p.m. to 566r.p.m. without the gear. The cone bearing is continuously lubricated by a stream of oil, the self-acting feeds are positive, contained in a box on the front of the headstock, and give four, eight, and sixteen cuts, or eight, sixteen, and thirty-two cuts per inch. The lathe is capable of taking a cut 1in. deep by ⅛in. feed at a cutting speed of 50ft. per minute, which means that it will reduce a forging 2in. in diameter at this speed and feed. The whole of the machines in this shop are driven by means of electricity from shafting and belting in groups.

The light machine shop and the screwing room are principally tended by apprentices, effecting considerable economy in labour costs. In the former department there are two very high-speed travelling cranes, each capable of lifting two tons, and made by Messrs. Marshall, Fleming & Jack. These are operated from the floor, so that the man who slings the weight to be carried also operates the crane. Among the machines in this department may be mentioned a vertical mill constructed by the Niles Tool Works, for the purpose of boring cylinder liners up to 4ft. 6in. in diameter and 6ft. long. It is capable of getting a cutting speed of 60ft. per minute on steel. The screw room is occupied by a series of automatic and semi-automatic screw and stud making machines, principally constructed by Messrs. Alfred Herbert

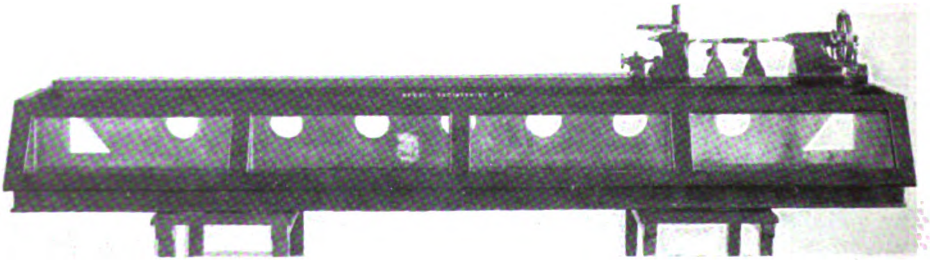


FIG. 15. MEASURING MACHINE.

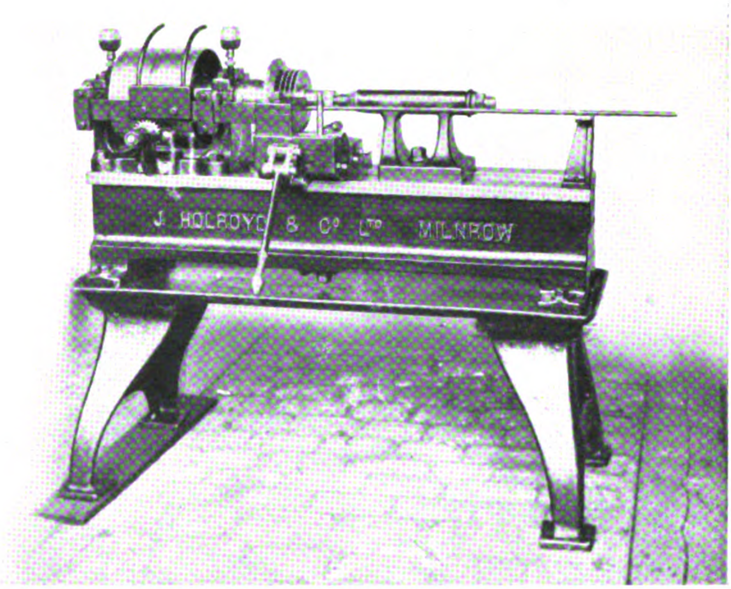


FIG. 17. SPECIAL ROD-CUTTING MACHINE.

Ltd., and driven in groups by electric motive power. As all the screws, studs, &c., required by the firm in its various departments are made in these works, there is a series of automatic stud machines with magazine attachments, shown in Fig. 14. This type of machine is too well known to require detailed description, but it may be mentioned that a cam shaft driven by worm gearing, and which can be driven fast or slow for any portion of its cycle—the changes being made automatically—operates the various motions. It is thus possible to feed the tools while cutting on a slow speed and to use the fast speed in order to withdraw the tools, rotate the capstan, bringing the tools into position to commence cutting and operating the chuck and bar feeds. The studs are made in two operations, the first consisting of screwing, ending and parting off, and the second by chucking from a magazine, screwing and ejecting. These single-slide machines are capable of making studs from bright or black bars, which have not been previously turned, up to $1\frac{1}{4}$in. in diameter. The method of drive adopted in this shop is by means of belting on overhead shafting connected to the motor. The whole of the tools, gauges, &c., required in the fitting and machine shops above described, together with the turbine blade department, are standard, and brought to gauge in a specially built tool room, having a full complement of grinding, drilling and milling machines of great accuracy, in order to assist in preserving perfect standardisation. A measuring machine constructed by the Newall Engineering Co., Ltd., is placed in this department, Fig. 15 showing the complete machine, while Fig. 16 illustrates the headstock. This machine is graduated to give readings down to $\frac{1}{10000}$th part of an inch. The graduations on the measuring wheel are arranged so that the size indicated can be read in decimals of an inch. An automatic adjustment is provided to keep an even, constant tension on the measuring screw, and compensation for error in the measuring screw is made by a special device. The indicator is of the spirit-level type, the level being curved, and any tilt given to it due to pressure on the anvil is magnified enormously, the movement of

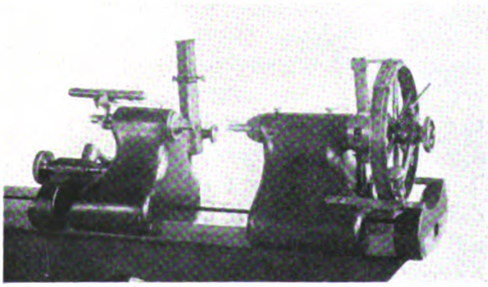


FIG. 16. HEADSTOCK OF MEASURING MACHINE.

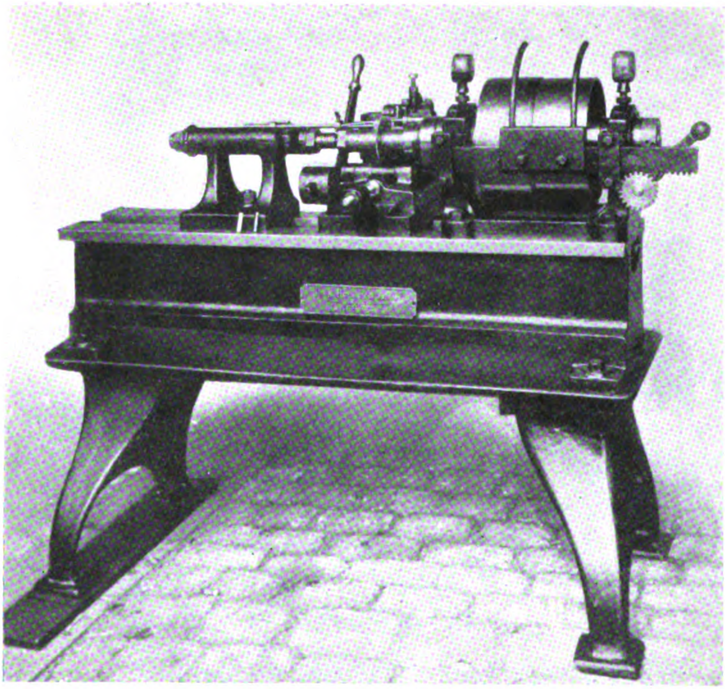


FIG. 18. SPECIAL TURBINE BLADE-NOTCHING MACHINE.

the bubble being 4,000 times that of the anvil.

The turbine blading department, which is a development rendered necessary owing to the extreme rapidity with which marine turbines are becoming standard practice in warship and mercantile marine construction, is fitted with a most up-to-date series of tools for producing turbine blades in an almost automatic manner. The material is brought in in the form of long rods of the required section and cut off in a Taylor & Challen press, which cuts and serrates the blades at the rate of approximately one hundred a minute. The caulking pieces are cut to length by means of a special machine made by Messrs. John Holroyd & Co., Ltd., the bar resting on a flat support at the right-hand end of the bed, and being pushed against a table disc, which automatically sets the bar as the operator puts the cross slide on to the saws. The bed is 4ft. long and the machine has 7in. centres, and is shown in Fig. 17. The blades are then notched in order to receive the binding wire which supports the outer periphery, and this machine is also supplied by Messrs. John Holroyd & Co., Ltd., and is shown in Fig. 18. It will be seen that a cross slide bolted to the bed carries a vertical slide with a special link-locking device by which the blade is first gripped and then forced down against the saw. Stops are provided to set the blades properly, the vertical slide being brought up by springs. The machine, which carries a 4in. nicking saw, will take blades up to 24in. long. After the blades have been nicked, they are tipped at their outer end by means of a special taper cutter, designed by Messrs. Parsons, Ltd., so as to remove unnecessary strength at the end, making the blades susceptible to easy wear in the case of touching, this being preferable to the blade stripping due to excessive rigidity. An interesting attachment in this department is the portable milling machine for turbine cylinders, constructed by Messrs. Palmers. This machine is designed for cutting grooves in turbine cylinders and consists of a base slide, which has two end flanges, enabling the machine to be clamped to the flanges of the turbine cylinder. On this base slide is mounted a compound slide carrying the vertical slide. The cutter head is fitted to the vertical slide, and is adjusted in this direction by hand wheel and screw gearing. The drive is obtained from a pneumatic drill motor carried on the cutter head. It will be seen that the application of pneumatic drive is of utmost value in turbine construction.

It will be impossible to do more than briefly summarise the remaining departments of Messrs. Palmers' equipment for marine constructional purposes, inasmuch as our space has been taken up by showing the way in which electric power is now applied to up-to-date machine shop equipment. It must not be forgotten that the boilers, as well as the engines and turbines, are made by the firm for their own and other people's requirements. In the boiler shop the main drives are at present controlled by a high-class compound surface-condensing steam engine, but for crane and lighting purposes electricity is employed. Heavy marine boilers can be turned out at the rate of one per week, and in addition a speciality of the department is the manufacture of the well-known water-tube boiler (see Fig. 22) which is the invention of Mr. J. W. Reed, the manager of the engine works department. Owing to the very large size of plant required in the boiler shops, hydraulic power is extensively used. Figs. 19 and 20 show two typical machines in this department, constructed by Messrs. Hugh Smith & Co., Ltd., of Possil Engine Works, Glasgow. The first is their patent hydraulic boiler shell riveting machine, capable of putting a pressure of 150 tons to close the plates, and 150 tons to form the rivet. The machine has a 12ft. gap, and, as will be seen, is of very powerful construction. The vertical plate-bending rolls are adopted for bending heavy boiler plates for the marine type of boiler made by the firm, and will take plates cold up to 12ft. 4in. broad and 1⅝in. thick, the rolls being made of forged steel and the two back rollers being supported on roller bearings. The front roller is made with an eye on the top gudgeon, and with the bush so arranged that the roller can be drawn up by the crane for the purpose of taking off the plates when these have been bent to a complete circle.

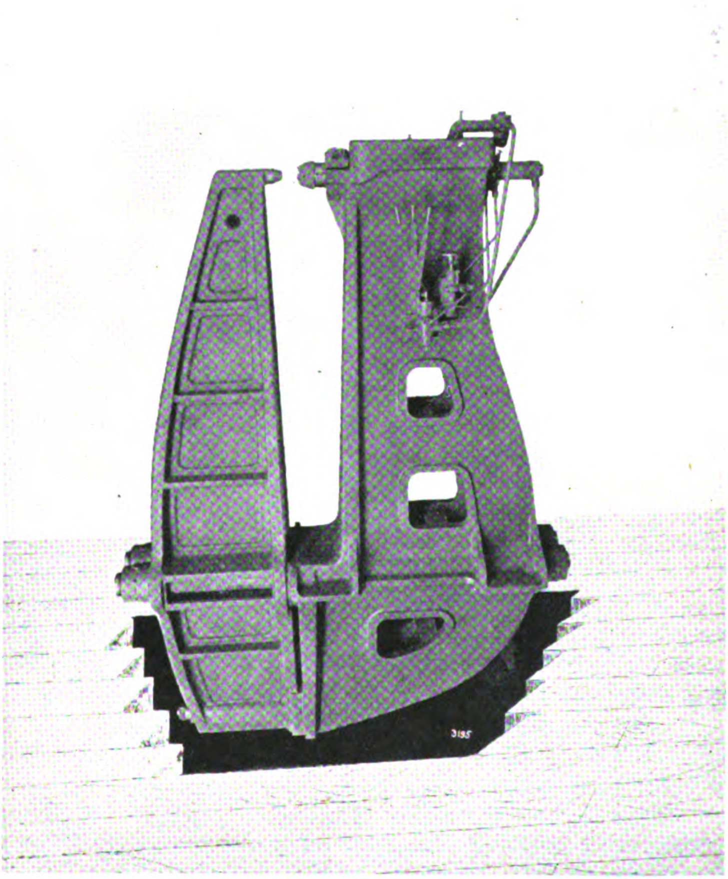


FIG. 19. HYDRAULIC BOILER SHELL RIVETING MACHINE.

Among the other machines in these shops are a plate-edge planing machine, capable of taking a plate 35ft. by 12ft. wide, and planing two edges simultaneously, a 200-ton

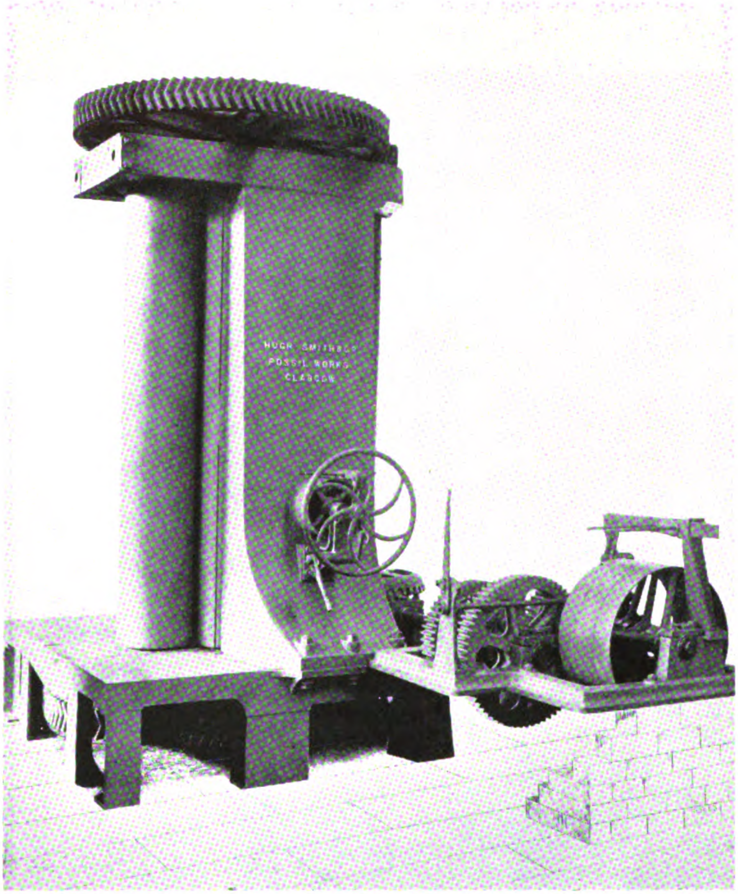


FIG. 20. VERTICAL PLATE-BENDING ROLLS.

hydraulic flanger, a special boiler shell drilling machine with four drilling heads, a two-headed machine for drilling and tapping holes for stays and stay tubes, and screwing the stays of tubes into position without the use of hand labour, together with a large number of other special tools. It should be mentioned that vertical rolls for boiler shell plates were first used in Messrs. Palmers' works.

The brass foundry and the blacksmiths' shops are two of the more recent additions to the works equipment, and deserve consideration from the point of view of electrical equipment. In the former department there is a 10-ton electric crane for handling the castings, and auxiliary machinery, such as the pneumatic compressor for the chipping tools, grinding machines for dressing castings by means of carborundum wheels, and a special machine for washing the floor refuse and ash of the foundry in order to recover brass, and which consists of an inclined dish carrying a heavy ball, through which dish a stream of water bearing the refuse is passed, reducing it to a fineness preparatory to separation and recovery, are electrically driven. In the blacksmiths' shop twenty-eight hearths are supplied with blast from a pressure fan direct-coupled to a 30b.h.p. British-Westinghouse motor running at 860r.p.m. An interesting feature about the arrangement of these hearths is that all fumes are led away to a central duct under the floor, and exhausted by means of a vacuum fan, giving 3½in. vacuum by water-gauge and driven by a 25b.h.p. Westinghouse motor. This keeps the atmosphere of the blacksmiths' shop exceptionally cool and clear, rendering it probably one of the finest examples of such an establishment in the country. The hammers, which are made by Messrs. C. & A. Musker, Liverpool, are of 10cwt. and 5cwt. size, and are driven by an air pressure of 100lb. per square inch. A motor is mounted directly on the wall, being of special side construction, for driving a small Pilkington hammer for light forging work. A switch-

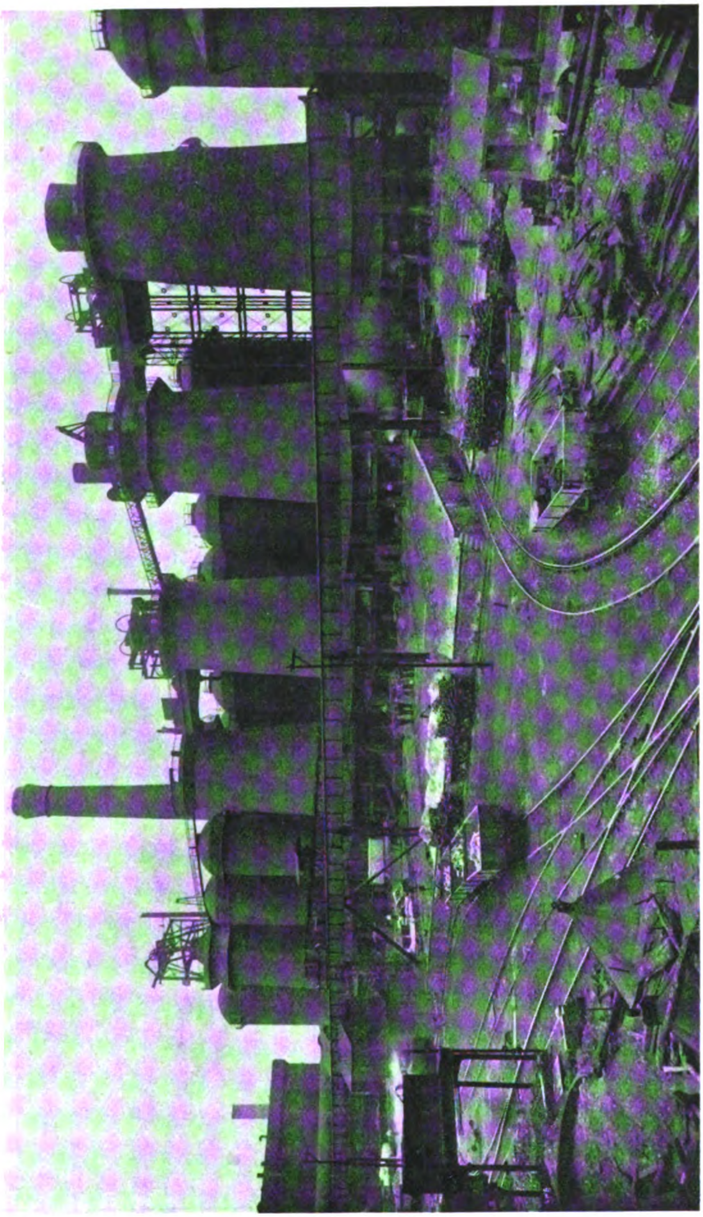


FIG. 21. GENERAL VIEW OF THE BLAST FURNACES.

board for this department was constructed by Messrs. Palmers' own electrical staff.

Both in the pattern shop, where a 30h.p. motor drives shafting which operates circular saws, planing machines, lathes, band saw, &c., the metal foundry where the cranes are electrically driven, and in the brass finishing shop, where there are miscellaneous tools for grinding, drilling, &c., the dominant features are, firstly, the care with which every stage of the firm's work is carried out by means of modern equipment, and, secondly, the extensive use which is being made of electric drive. As an example of the completeness of the firm's equipment may be mentioned a tool which would be considered in many

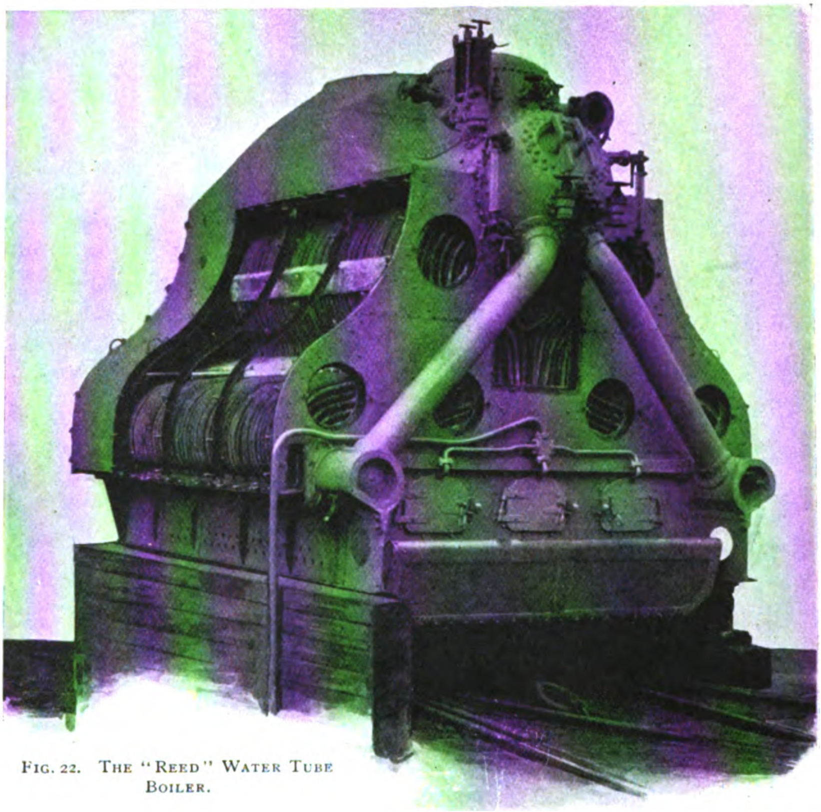


FIG. 22. THE "REED" WATER TUBE BOILER.

shops rather a refinement, but yet which amply justifies its existence at Messrs. Palmers'. This is a pantographic tool for engraving name plates, constructed by Messrs. Taylor, Taylor & Hobson, Ltd., of Leicester. This, by means of a pantographic action, is capable of engraving letters, figures, and other designs on metals either in relief or in intaglio, the size of the letters ranging from $\frac{5}{8}$in. to $\frac{3}{32}$in.

There is always a difficulty in describing the operation of works of such large size as those of Messrs. Palmers' Shipbuilding and Iron Company, Ltd., to preserve balance between the various parts of the description, and the above notes by no means exhaust the importance attaching to the subject as an example of the application of electric power to the production of iron and steel, and in marine engineering. It is hoped, however, that they may to a certain extent provide a suitable line of thought for other engineers who are contemplating the electrical equipment of similar industrial concerns, and the author has to acknowledge the very great courtesy which has been shown to him by Mr. J. W. Reed, the manager of the engine works department, and Mr. Douglas Upton and Mr. James Prosser, the manager and engineer respectively of the steel and iron works department, in providing him with ample facilities for obtaining technical information for the present article. Mention must also be made of the courtesy of Mr. Malcolm Dillon, the Local Director of the Company, for granting him in the first place permission to examine the operations of the firm, which ranks among the first of its kind in the United Kingdom, and possibly in the whole world.

J. A. SEAGER.

ELECTRIC PLANT AT THE PANTYFFYNNON COLLIERY.

ONE of the first mining concerns in the Carmarthenshire district of South Wales to use electrical power for operating its plant was the Park and Blaina Colliery Company, Pantyflynnon. At these collieries there has been in operation during the past seven years a three-phase plant, and its capacity has lately been increased to about 400h.p. Electrical energy is used for pumping, haulage, and screening purposes, and as the steam generating plant does not call for special notice the electrical plant only will be described.

One section of the colliery consists of a main slant about 1100 yards in length, and dipping 12in. in the yard. By the side of this is an air slant about 1200 yards in length, with a dip of 2ft. in the yard, these two slants being connected by a level at a distance of 1100 yards from the surface. The two slants are also connected about 600 yards from the surface by a cross measure drift. Owing to the heavy dip which exists for the greater part of the length of the air slant the expense of hauling the coal worked from the headings driven from this side of the workings would be prohibitive, so to avoid this the coal is hauled up as far as the cross-measure drift, through which it is hauled to the main slant and thence to the surface.

The workings consist of a large number of levels driven over a wide area, and as the gradient in some of them is rather steep the conditions of haulage are somewhat severe. The question of providing an economical method of haulage has, however, been satisfactorily solved by installing a very complete system of electric haulage at suitable points.

The second section of the colliery consists of a pit situated in the Park district, about one mile distant from the Pantyffynnon workings. The application of electric power is at present, however, confined to the Pontyffynon workings, the power-house being situated between the two slants. The situation of the power-house is, therefore, ideal for power transmission purposes, and this fact was not lost sight of by the company's electrical engineer, Mr. G. Thomas, when setting out the underground system of distribution, as will be seen later on. The generating plant consists of a 90kw. Brown-Boveri 500-volt, 40-period, three-phase, star-connected alternator, having a direct-coupled exciter. This set is rope-driven by a Marshall cross-compound engine taking steam at 125lb. pressure and developing 100h.p. The speed of the alternator is 440r.p.m. This set represents the first portion of the plant which was installed by the Corlett Electrical Company about seven years ago. The latest addition to the generating plant consists of a 220h.p. compound double-acting two-crank Bellis and Morcom engine, direct-coupled to an A.E.G. 187k.v.a., 525-volt, 40-period, three-phase, star-connected, flywheel alternator running at a speed of 400r.p.m. The exciter is carried on an extension of the alternator shaft, and has an output of 4kw. at 115 volts.

Energy for lighting the colliery is supplied by a direct-current shunt-wound generator having an output of 5kw. at 115 volts at a speed of 430r.p.m. This generator is direct-coupled to and mounted on the same bed-plate as a Marshall high-speed vertical engine taking steam at 100lb. pressure and having an output of 11h.p. at a speed of 435r.p.m. when working non-condensing; this set also serves as an auxiliary source of excitation

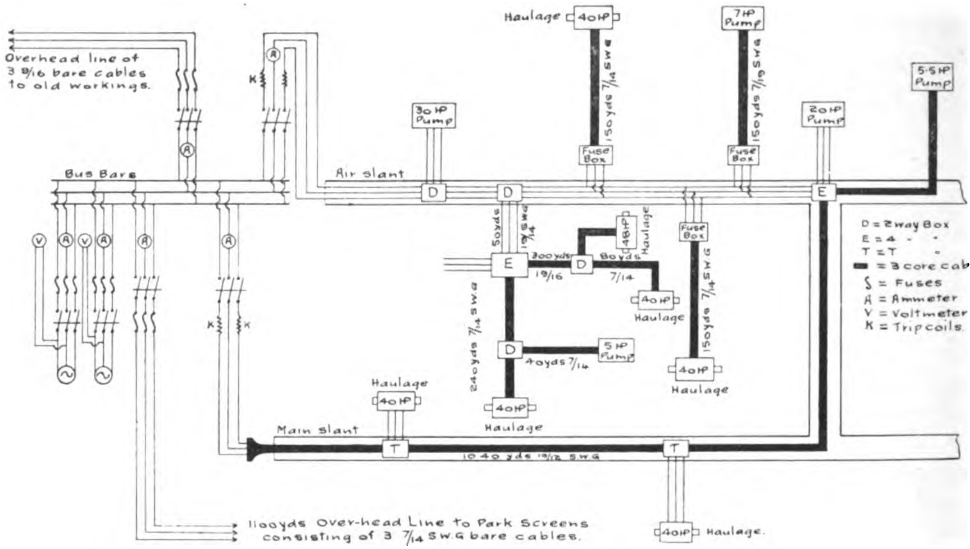


FIG. I. DIAGRAM SHOWING THE ELECTRICAL TRANSMISSION SYSTEM OF THE PANTYFFYNNON COLLIERY.

for the main generators. These two sets, forming the extension to the generating plant, were supplied by Messrs. The Electrical Company, Ltd., who also supplied the necessary extensions to the main switchboard consisting of two generator and feeder panels provided with the usual instruments and switchgear. The steam side of the generating plant exhausts into a Worthington jet condenser which gives a vacuum of 26in. The load on the generating plant consists of seven haulages, seven three-throw ram-pumps, three Sulzer turbine pumps, one air compressor driven by a 35h.p. motor which is used for operating boring drills, also one 30h.p. motor for driving the screening plant at the Park colliery—the whole representing a total of twenty-one motors including spares.

From the above description it will be seen that the generating plant has to deal with a widely fluctuating load, due chiefly to the frequent starting and stopping of the different haulages. The question of voltage regulation is therefore of great importance in such cases, and when this plant was first started, great difficulty was experienced in obtaining satisfactory regulation, notwithstanding the fact that a man was constantly kept at the switchboard. This difficulty has now, however, been entirely overcome and satisfactory regulation obtained by installing a Tirrill regulator, which was supplied by the British Thomson-Houston Company. This apparatus is particularly adapted to colliery installations of moderate capacity where it would not pay to keep a man constantly at the switchboard, the advantages to be obtained from its use being (1) better regulation than is possible with hand control; (2) a reduction to a minimum of the amount of skilled attention necessary, an advantage which should appeal particularly to colliery managers.

As regards the underground distribution, this has been arranged by the manager, Mr. Roblings, and Mr. Thomas on the ring main system, this being rendered possible by the ideal situation of the power-house regarding its position in relation to the underground workings. A complete diagram representing the arrangement of the circuits both above and below ground is shown in Fig. 1, a reference to which clearly shows that the introduction of the ring main system will have the effect of greatly reducing the voltage drop. As it is very unlikely that both sides of the ring main would be fully loaded at the same time, the side carrying the lighter load would act as a feeder for the heavier loaded side, thus reducing the drop on the system. The advantages of the ring main system in colliery workings cannot be over-rated from the points of view of economy and latitude in working, but unfortunately its application is not always possible in colliery work.

The motors used for underground work are of the slip-ring type with the exception of three small pump motors which have squirrel-cage rotors. There are several makers represented in the motors used. The motors supplied by the Electrical Company for underground work include a 48b.h.p. intermittently rated motor running at a speed of 576r.p.m. and specially designed for haulage work. The slip-rings of this motor are brought outside the frame and totally enclosed, the motor being controlled by a vertical reversing oil-immersed controller provided with separate resistances of the grid type. For driving machine tools on the surface this company have also supplied a 25h.p. slip-ring motor running at a speed of about 770r.p m. and started by means of a liquid starter. Also a 5h.p. squirrel-cage motor operating at about the same speed and used for pumping purposes. The underground plant also includes four haulage gears, each driven by a 40h.p Brown-Boveri slip-ring motor and two other haulages each driven by a 40h.p. British-Thomson-Houston slip-ring motor. It is of interest to note that the latter company have just received an order for the supply of motors of similar capacity for driving three other haulages in course of erection.

As already stated, pumping operations are carried out by seven three-throw ram pumps and two Sulzer turbine pumps (in these workings) of different capacities. The motors used for driving the ram pumps vary in ouput from 5h.p. to 30h.p. and have been supplied by Messrs. Brown-Boveri, The Lancashire Dynamo and Motor Company, and Mather & Platt. The turbine pumps are driven by motors supplied by The Electrical Company and Brown-Boveri. They are of the portable type and are used to deal with any sudden inrush of water liable to occur at different parts of the workings. For this reason they are only of small capacity, viz., 50 gallons and 30 gallons per minute against 120ft. and 50ft. heads respectively. A rough idea of the arrangement of the various haulages and pumps is given by the diagram in Fig. 1, which also

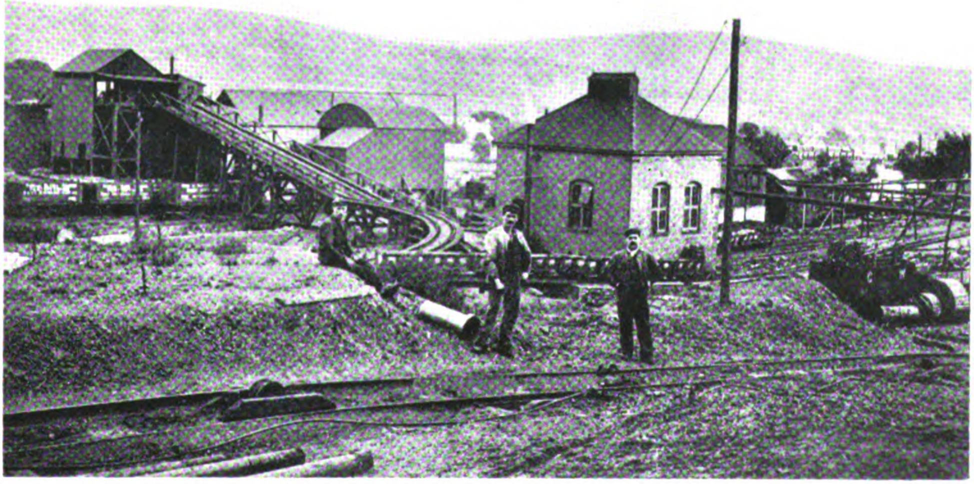
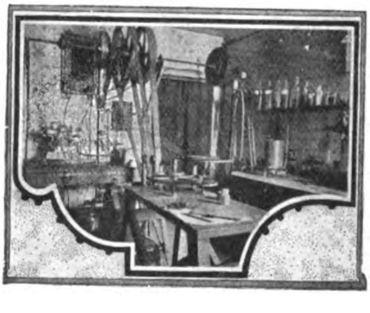


Fig. 2. General View of Screening Plant, &c., at the Pantyffynnon Colliery.

shows that the underground distribution is carried out partly by three core and also by mains consisting of three separate cables. These cables are all supported on insulators and slung as near the roof as possible. The importance of having a well-laid-out system of underground cables cannot be over-estimated from the point of view of safety and freedom from faults, and especially is this the case when energy is transmitted over a large area, as is the case at this colliery.

In connection with this installation there are two transmission lines. One line transmits power to a screening plant in the Park district. It is about 1100 yards in length and consists of three bare copper wires of 7/14s.w.g. supported on poles placed 40ft. apart, at a height of 20ft. above the road. Owing to its proximity to a number of telegraph and telephone wires it is protected over the greater part of its length by screen wires which are well earthed. The line is protected from lightning discharges by Wurtz arresters placed at each end. A second transmission line conveys power to some old workings which are to be unwatered by a five stage Sulzer turbine pump having a capacity of 250 gallons per minute against a total manometric head of 300ft. This pump is driven by an 80h.p., two-pole, 470-volt, 40-period, three-phase motor provided with a short-circuited rotor. This motor runs at a speed of 2340r.p.m., and was supplied by the Electrical Company. The transmission line, which is 700 yards in length, consists of three 19/16s.w.g. bare copper cables supported on poles at intervals of 40ft., having lightning arresters at each end.

In conclusion the writer's thanks are due to Mr. Roblings, Mr. Thomas, and Messrs. The Electrical Company, Ltd., for much information dealing with the above plant.



THE ELECTRIFICATION OF STEAM-DRIVEN NON-REVERSING ROLLING MILLS.*

In estimating for the electrical equipment of an existing steam-driven mill it is usual to take a series of continuous indicator diagrams of the engine, the mill for the time doing its hardest work. These diagrams are useful as a check from which to calculate the power of the motor to be installed, but great care must be taken not to place too great a reliance on the horse-powers as calculated from such diagrams. Allowance must be made for the increased output and heavier duty required of the motor due to the higher average speed, with consequent greater output following on the more even torque exerted by the electric motor as compared with the very uneven turning effort of the steam engine, and in these days it is better to estimate the horse-power of the motor by calculating the work it will be called upon to do from the data already obtained under the same or similar conditions. Knowing (1) the total output of the mill during a certain period; (2) the nature, size, and section of the raw material; (3) the size of finished product; (4) the cycle of operations—that is, the number and time of the passes, and the period of rest—it is possible, by comparison and from figures already known from other installations, to estimate very closely the horse-power of the motor to be installed.

A properly designed flywheel is of great assistance in reducing the size of the motor and enabling it to get over the peak loads without absorbing too great a current from the line. The tendency of the motor to slow down, due to a heavy load coming on, causes the flywheel to give up its energy, and as the load decreases and the motor speeds up energy will be returned to the flywheel. The ideal condition for a flywheel is when the highest load on the mill is accompanied by a reduction of the motor speed from the maximum to the minimum limit, so causing the flywheel to give up the greatest possible amount of energy, reducing thereby the demand made on the motor and by the motor from the line. This period should be followed by a light load period, allowing the motor to regain its normal speed and restore the lost energy to the flywheel. It should be remembered that the time taken to extract the energy from the flywheel is usually considerably shorter than the time required to return the same amount of energy to it, assuming that it is desired to maintain the demand from the line as nearly constant as possible. In the perfect case the light load period is equal to or greater than the overload period. The use of a flywheel for levelling the output demanded of the motor is not generally practicable if the time in rolling one pass exceeds about 30 seconds, and in such cases the introduction of a heavy flywheel would be open to very serious objections, inasmuch as the motor would, after a certain point in the pass, have to pull the flywheel round in addition to supplying the power required for rolling. This is the case in rolling long bars, rails, &c., and here a comparatively light flywheel is desirable, levelling only the smaller peaks and variations in the load, the motor being designed to deal with the main peaks without any external assistance.

In those cases where a heavy flywheel is employed with the object of relieving the strain on the motor, it is usual to employ an automatic device to ensure that the flywheel carries its fair share of the load. With direct-current machines the motors are always compounded, but to further increase the strength of the field use is made of a separate excitation, which increases the field current, so reducing the speed still further and obtaining a return of the flywheel energy during the correct period. With alternating equipment a slip regulator is employed, automatically introducing a resistance in the rotor circuit at times of heavy load; the resulting effect, however, is the same and is independent of the electrical characteristics of the installation. As a general rule it can be stated that, with a properly designed flywheel, the fluctuations of loads are only one-half of what they would be were the flywheel effect not utilized.

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* Abstract of Paper by W. F. Mylan; the Leeds Local Section of the Institution of Electrical Engineers, May 5, 1909.

The proper place for the flywheel is, of course, on the highest running shaft; but this is not usually feasible, and consequently it is generally found that the flywheel is fitted on a motion direct geared to the mill, thus preventing the extra strain on the motor and its gears or ropes.

Flywheel equalisers are occasionally employed to level up the demands on the power supply, but these are open to the same limitation as the direct use of a flywheel, and necessitate the motor being made large enough to deal with the maximum overload.

In merchant mills it is an advantage and practically a necessity to be able to vary the speed of the mill motor. With a direct-currrent power supply this is a comparatively simple matter, and it is quite easy to obtain direct-current motors which are capable of giving their full normal output over a wide range of speed, the speed variation being obtained by means of field regulation only. In such cases the efficiency of the motor is to all intents and purposes unaltered by variation in speed, but unfortunately the same cannot be said where the source of power is alternating-current. The only practical way of reducing the speed of an alternating-current motor is either by the introduction of resistance into the rotor circuit, or by choosing a suitable combination of the number of poles in the stator and distributing the stator winding to suit, to run at two or at the most three speeds with economy, these speeds being obtained according as the windings are connected to give one-half or one-third the normal number of pairs of poles. In the first case, speed reduction is obtained by means of, usually, a liquid type of controller, and over a very wide range, but with serious loss in efficiency (roughly the efficiency of an alternating-current slip-ring motor decreases in the same proportion as the speed decreases); and in the second case, a special controller grouping the stator windings in a suitable manner will give only two, or at the most three speeds, but give them with an efficiency only a few per cent. below the maximum. An attempt has been made to overcome the difficulty by adopting, in cases where a speed reduction is desired, a device in which the motor shaft carries a three-step rope pulley, and the necessary lengthened shaft is supported at its free end by a pedestal bearing, the whole being carried on a base plate mounted on slide rails. In the event of a different speed being desired, the motor bedplate is slacked back, the ropes changed to the desired group of pulleys, and the motor drawn back to tighten up the ropes. In order to carry this alteration through in the minimum possible time, a small motor is usually fitted to operate the sliding baseplate screws, and under such conditions it is remarkable what a short space of time is required to make a change. In an installation of this character the men are accustomed to make the change in some three or four minutes, this time representing the period under normal circumstances and without any special effort. Such an arrangement has the disadvantage that only certain predetermined speeds are possible for the mill, but against this may be set the fact that the motor is working at full speed continuously and consequently operating with the best possible efficiency—a most desirable condition.

The method of transmitting the power from the motor to the mill rolls is worthy of careful investigation if the best possible results are desired from the change, and the opportunity should be taken to cut out any inefficient and unnecessary gearwheels, uneconomical drives, &c. Very often local conditions render it impossible to adopt that which is evidently the best, but usually some considerable economy can be obtained with the introduction of a new form of drive. In the large majority of cases it is impossible to direct couple the motor to the mill, and some form of speed reduction is essential. In such instances, however, where the motor can be direct-coupled, it is advisable, with the view of reducing the sudden shocks and strains on the motor, to introduce a flexible coupling. The extremely favourable results which have been obtained by the introduction of such a coupling more than justify the extra expenses incurred, and there is, moreover, no difficulty in obtaining flexible couplings which are capable of standing the most severe service met with. The slow speed of a mill compared with the size of the motor required render it advisable in most cases, on account of capital cost and the difficulty in manufacturing slow-speed machines having really satisfactory electrical characteristics, to put in a high-speed machine and reduce by means of gears or pulleys to the required speed. Rope pulleys are often used to obtain this end, and have the same effect as the flexible coupling in the case of the direct-coupled motor. Where gears or direct coupling are adopted it is most important that the bearings of the motor should be properly designed, and also that the bearings of motors used in rolling mill work should be of more massive construction than is usual, and thoroughly well lubricated. With a properly proportioned bearing, a babbitted shell with ring lubrication is quite satisfactory, but on the larger sizes of motors it is sometimes desirable to introduce a proper system of forced lubrication with a suitable water-cooling device.

Owing to the heavy and frequent overloads that the motor must deal with, the shaft must be stiffened, and great care must be taken to see that the end windings of the motor are properly braced to prevent distortion. Where slip-ring motors are employed the rings should be of ample section. Occasionally one meets with motors where the smallness of the rings has a serious effect in very much reducing the overload capacity of the motor owing to the smallness of the rotor currents, which can be dealt with without excessive sparking and heating at the rings.

A great feature of any electrical equipment is the ease and absolute certainty with which the control of the motor is effected. The provision of a suitable outfit of recording instrument is to be recommended. Such an outfit should consist of a recording ammeter or wattmeter, showing the momentary fluctuations in the load on the motor, and an integrating wattmeter totalling up the power taken over a certain period. By keeping a correct log of these data it is easy to determine accurately the cost of rolling each particular section. A circuit-breaker should always be provided in the main circuit of the motor, the breaker being fitted with overload and no-volt release. The provision of a no-volt release is important, as this allows of the fitting of emergency switches at each housing and other suitable points, allowing the mill to be quickly stopped in case of necessity from any of several points. These emergency switches open circuit the no-volt release coil of the breaker, thus opening the breaker and cutting off the supply of current from the motor. For starting large motors, from all points of view a liquid controller is to be recommended. Such controllers, as now built, are highly satisfactory in operation, and require little or no attention beyond an occasional addition of clean water to the liquid. The gentle starting and the comparatively small floor space occupied more than counterbalance this little extra attention required. Large controllers of this pattern are usually fitted with cooling coils, the consumption of water for this purpose being about 3.3galls. per hour per h.p. dissipated. For the best results the temperature of the resistance liquid should be between 60deg. C. and 80deg. C. Occasionally it is advisable to clean the controller thoroughly, and to fill up with new solution.

The author was able to give particulars of several conversions which have been carried through successfully, these covering mills actually in commercial operation at the present time which were originally driven by steam engines.

Cold Rolling Brass Merchant Mill.—This mill consists of one set of breaking-down rolls, one set of second breaking-down rolls, and two sets of finishing rolls. The breaking-down rolls are 20in. diameter, 30in. long, and all are driven at 6r.p.m. by a long train of gear-wheels. Originally this mill was driven by a single-cylinder horizontal non-condensing engine, 28in. diameter, 4ft. stroke, and run with a boiler pressure of between 60lb. and 80lb. per square inch. The engine was fitted with an ordinary D slide valve and flyball throttle governor.

The usual size of ingots dealt with in this mill are 3in. by 1½in. by 7ft. These ingots are rolled down to various gauges, No. 8 being about the average and also the usual size. In such a mill as described above, the ingot is first rolled into strip; this strip is then put through the cutting-up machine, resulting in pieces of rectangular section, which are then passed on to the draw benches to be drawn into ordinary brass wire.

The motor is a 200h.p. 25-period 400-volt 3-phase 240-revolution slip-ring motor, and it is direct geared, by means of cast-iron gear, to the mill. The gear ratio is about 4.8 to 1, the gears being 3½in. pitch and 12in. face. The motor is fed from the secondary of a 3-phase 5000-volt to 400-volt transformer. No flywheel is provided, and consequently the overloads are dealt with directly by the motors. In this case the sustained overloads render a flywheel useless. Starting of the motor is carried out by means of a liquid starter, and an interesting feature is the installation of a number of emergency switches which, when used, open circuit the no-volt attachment on the primary switch (oil-break pattern) supplied. This equipment has proved extremely satisfactory in operation, and the ascertained consumptions per ton of material dealt with have come well within the anticipated results. A feature is the great saving of floor space occasioned by the installation of a motor in place of the original steam engine.

A better example of such saving is seen in the case of a similar mill. Here the motor has an output of 250h.p. at 250r.p.m; it is of the slip-ring type, and in general exactly similar to the above outfit. The motor is direct-geared to the mill, and is placed underground, thus giving a very large additional flooring space, which, as this mill is in the heart of a large city and rather confined for room, is of the greatest possible value. This mill has two breaking-down rolls and six finishing rolls, as before, driven by a train of wheels. The ingots dealt with are of brass 10in. wide, 1in. thick, and varying from 16in. to 18in. long.

The original engine worked with a boiler pressure of about 50lb. per square inch; had a single cylinder of 25in. diameter by 4ft. stroke; and ran at 53r.p.m. The engine ran condensing, and it is interesting to note that the condenser was much too small for the engine at full load. At no-load the engine indicated 60b.h.p., the average load was 120b.h.p., and the maximum load 235b.h.p.

The mill was designed for and deals with brass and white metal; the average output has been considerably increased since the mill was converted. It has been found on the average that breaking down 10in. by 1in. by 12in. brass ingots into strips for wires takes 86 units per ton. This mill has shown a very large saving over the original equipment.

Iron and Steel Merchant Mill.—A mill

rolling a large variety of sections has been in constant use for some three or four years, and as the result of the experience gained a second mill was converted to the electric drive. The sections of steel rolled consist principally of—

Rounds, ¾in. to 2⅛in. diameter from 4in. billets.
Flats, 1in. by ⅛in. to 7in. by 1in. from old rails.
Squares, ¾in. to 4in. from 4in. billets.

The steels used are of varying hardness and range from 0.2 to 1.2 of carbon.

The mill consists of 5 pairs of 12in. rolls running at 80r.p.m. as a minimum, and is driven through double helical steel gears, ratio 1 to 2.5. In this mill the 5 pairs of rolls practically comprise two mills having two gangs of men who work quite independently of one another. It thus often happens that several passes are made at the same moment, but as the motor is very generously rated no difficulty has been experienced through an exceptional load coming on and pulling up the motor. The supply in this case is direct current, and the motor has a normal output of 200b.h.p. at from 200r.p.m. to 450r.p.m. The machine is fitted with commutating poles, speed variation being obtained by the use of a field rheostat. As the rating of the motor is extremely liberal, overloads of 100 per cent. and 150 per cent. can be carried for fairly long periods without sparking or harm to the machine. The steam engine which this motor replaced was a very old beam engine, but this fact does not in any way discount the saving which has resulted.

Since the mill was electrified an increase of output of over 30 per cent. in material rolled and a decrease in the power consumed by 60 per cent. have been obtained. These figures have been ascertained by a careful log over a long period, and are certainly a remarkable tribute to the advantage of the electrical drive. The works in which these mills are installed have a very large power plant consisting of gas and turbine-driven machines, and consequently the cost of power per unit generated is very low.

Sheet Iron Mill.—A very good example of a mill of this pattern is being operated by a 350b.h.p. slip-ring motor off a power company's supply. The mill has three pairs of housings of the two-high type barring, roughing and finishing rolls, and deals on an average with 600lb. blooms, rolled into sheets 10ft. by 4ft. by $\frac{1}{16}$in. The motor is designed to run normally at 400r.p.m. when fed from a three-phase forty-period 400-volt supply. It is fitted with rope pulley 4ft. 6in. diameter arranged for twenty-two 1½in. ropes, the outer end of the shaft being carried on a pedestal bearing, and the whole carried on a bed-plate and slide rails.

The control of the motor is effected by means of a hand-operated liquid starter and regulator, the controller being fitted with cooling coils as previously mentioned.

The motor drives by means of the ropes on to a second pulley 10ft. 6in. diameter and weighing 14 tons. The shaft of this pulley is geared to the mill, ratio 1 to 3.75, giving a normal speed of the mill of about 45r.p.m. The gears are 17in. face 4½in. pitch.

Steel plates are rolled from billets, and in an actual case two billets each 3ft. by 8½in. by ⅞in. have been rolled into strips each 8ft. 3in. by 33in. by 0.064in. in from 120 to 150 seconds. This period covers five or six roughing passes and twelve to fourteen finishing passes. The consumption of power in this particular mill was 6.5 units per pair of billets or 95 units per ton.

In a second example of work done by the same mill, the billets as before being dealt with in pairs, two billets each 4ft. 2in. by 10in. by 1⅛in. were rolled down in eight or nine roughing passes and five to eight finishing passes to sheets each 8ft. by 4ft. by 0.080in. at an energy consumption of 70 units per ton (10 units per pair of billets), the time for one rolling averaging 170 seconds.

Since having had experience of the above it has been decided to equip electrically a second and larger mill at the same works.

It is extremely difficult to obtain reliable figures as to the cost of rolling the different classes of material. For purposes of comparison, however, it is useful to know the power consumption for rolling different classes of material, and, knowing the cost per unit for the local condition, to arrive at some definite figure which will be a very close approximation to the actual power costs for a certain section. In any comparison of cost of rolling under the two methods of driving the only fair method of judging the relative merits is by the observation of the costs over a period: thus, in the case of a steam-driven mill including all stand-by losses, oil, waste, stores; and with the electrically driven mill making full allowance for the increased output or a similar output in less time.

For several of the figures given below the author is indebted to the paper by Messrs. Koettgen and Ablett before the Iron and Steel Institute; other figures are given representing the actual ascertained consumption from certain mills as determined by careful calculation and observation made over a long period.

Rails and Girders.—Re-rolling 90lb. rails of section 16lb. per yard, each piece 30ft. long, required 56 units per piece. Total output of mill 4800 pieces per 12 hours. Small mining rails rolled from billets 5in. by 5¾in. and weighing from 900lb. in the case of 28lb. per yard rails to an average of 650 in the case of 18lb. rails required as follows per ton rolled: 28lb., 38 units.; 24lb., 42 units; 20lb., 45 units; 18lb., 48 units. Smaller rails of 12lb. and 8lb. section require rom 49 to 54 units per ton rolled.

Girders 11in. by 6in. can be rolled for about 50 units, per ton.

Channels averaging 1½in. by ¾in. by 0.02in. require 66 units.

Angles 3½in. by 3½in. by ⅝in. from 800lb. billets require 50 units.

Sheets (iron), 8ft. 3in. by 33in. by 0.064in., 95 units per ton; 8ft. by 48in. by 0.080in., 70 units per ton; 10ft. by 48in. by 0.067in., 80 units per ton; 10ft. by 48in. by 0.125in., 60 units per ton; 9ft. 6in. by 42in. by 0.09in., 84 units per ton.

Breaking down 10in. by 1in. by 12ft. brass ingots into strip about No. 8 gauge, 86 units per ton.

Rounds and squares: ⅞in. rounds can be rolled at between 40 and 36 units per ton. The mill output is between 22 and 30 tons per shift. Average billet, 28in. by 4½in. by 4½in.

13/16in. round bars required same power. Output of mill, 46 tons per shift.

Bars 1in. to 2in. and 1in. to 7in. diameter from billets 5in. square require 38 and 40 units per ton. In this case the 1in. to 7in. bars were much shorter than the 1in. to 2in. bars, and consequently the consumption appears high.

Advantages.—As the torque exerted by the electric motor is maintained absolutely constant at a predetermined value and is quite independent of the momentary position of the motor, it is possible to run the mill at a considerably higher speed than formerly, and a better product with more uniform finish results. In one instance the speed of the mill has been twice increased, and this without any difficulty being met with in handling the material. In rolling at the increased speed it is found that though the speed is higher the rolls run more evenly, and the material coming away at a steady speed is quite easily caught and controlled when leaving the rolls. After a short time the men get accustomed to handle the product at the higher speed, and if on piece-work prefer it, as enabling them to earn more money in the shorter time.

Due to this constant turning effort of a motor as compared with that exerted by a one or two-crank steam or gas engine, the electrically operated mills are very free from stalling. This is largely due to the smooth running of the electric equipment; but when a tendency to stall does occur the motor slows down, extra energy is obtained from the flywheel and from the line, automatically tending to get the material through the rolls.

The ability to run a mill at a higher speed, or at any rate to keep a more constant speed on the mill, allows a much greater output to be obtained from the mill during the same time as compared with the steam driven mill, as owing to the good speed-regulating characteristics of the motor the mill will make a greater number of revolutions during a shift than the corresponding steam-driven mill, consequently a bigger output is obtained for the same period. The large overload capacity, which is an inherent feature of all electric motors, enables a widely fluctuating load to be dealt with, the speed variation under very extreme conditions being decidedly small; this results in the mill running much smoother and more quietly.

An increased output can also be looked for due to the convenient and rapid manner in which the mill can be controlled and handled.

The efficiency of the electrically operated mill as estimated by the actual cost of rolling as compared with steam-driven mills is beyond dispute. In this connection it should be borne in mind that the actual decreased power costs in rolling are not due so much to the fact that it is an electric motor doing the work, but that the electric motor enables one to either purchase power at low rates from one of numerous supply companies who operate in all large industrial centres, thus shutting down the wasteful steam boilers and local electric plant, or, in the case of a number of mills, to concentrate the power plant at one spot, generate in bulk at the lowest possible cost, and distribute the power to the exact points required, with an economy unapproachable by any other system. In these advanced days most works have a large electrical plant installed, extensions to which do not involve a very large capital expenditure; but in those cases where no plant exists or where the plant is small and incapable of economical extension, there is no question that the cheapest method is to take power from the outside source.

A very important advantage which follows on the introduction of electricity is the possibility of arriving at very exact figures (not approximations) of the actual power consumed under any conditions. This information being obtained for each section rolled, enables a very close price for rolling to be determined, which in these days of extraordinarily keen competition is most desirable. From such figures also, by careful inspection, it is possible to tell at a glance whether the mill is in good working order, or by making alterations and taking readings, to see whether the best possible method of handling the material and obtaining the desired result is being followed.

The extreme simplicity of the control and the ease with which it is possible to make electrical apparatus practically fool-proof, reduces the labour costs considerably, and this, coupled with the impossibility of an electrically driven mill racing, render less frequent the stoppages for broken couplings, pinions, and rolls.

Such troubles are inseparable from a steam-driven mill, and are a constant source of annoyance and a big loss, not only due to increased upkeep but to time lost by the mill having to stand whilst the repairs are carried out. The provision of simple and certain protective devices is easily arranged for which in emergency can be relied upon to operate with certainty.

A very material saving in floor space is certain where a mill is converted to electricity, and this is a great advantage as it enables the space around the mill to be used for the more rapid handling of the material required to feed the mill, and for the disposal of the finished product. Very often the motor can with advantage be installed below the floor level, the only gear on the shop floor being the comparatively insignificant control gear.

An electrically operated mill has in any case less stand-by losses, and in the case of the motor fed from a supply company's main, none at all. In comparing the cost of rolling under the two systems (steam and electricity) this point is important, as in one case the losses are very serious and add largely to the total cost of rolling a certain output.

Where a motor is employed for driving a mill a great advantage accrues through being able to start up immediately, and a further reduction in cost of rolling is obtained through less labour being required to handle the same material. A motor requires only intermittent attention, and with emergency devices for stopping it is not necessary to have an attendant standing by continually.

Finally, on the question of capital cost, speaking generally the actual electrical equipment of a rolling mill is at the worst only equal to, and in the majority of cases considerably cheaper than the corresponding steam equipment. If, however, electrification involves either the putting down of a generating plant or the extension of an existing plant, then there is no question that the electrification of the mill will entail the expenditure of a larger sum of money than that involved by putting down a new steam plant, and in such cases one must look in other directions to justify the conversion. Usually in any works having a rolling mill there are a great number of auxiliaries on which the existing drive can, with considerable economy, be replaced by one introducing the use of a motor, and it is the extra and more even load due to these motors that will justify the installing of a generating plant of capacity sufficient to carry the load on the mill and in addition that due to the auxiliaries. It would be impossible to run a plant feeding one mill only, and generate with economy, unless some other load less variable is also to be obtained, and consequently in such a case it is necessary to consider the broader scheme if any benefit from the electrification is desired. In the case of the works where a plant is already installed, and a comparatively cheap extension is all that is necessary, the problem is much simpler, and there is no difficulty in making out an excellent case for the electrification.

Supply companies in many areas provide a ready source of power for such works as have not or cannot justify the installation of their own plant, and offer a convenient and easy means to the electrification of the mill. Many mills are already in operation under such conditions, especially in Glasgow, Birmingham, and the North-East Coast districts, and have proved to be entirely reliable, operating at a much lower cost than under their old conditions. In one instance with power at 0.85d. per kw.-hour, a saving of over £3,000 was made on one year's working, more than paying for the cost of the equipment. The crux of the whole question of rolling electrically is whether or not a reasonably cheap source of power is obtainable either from a private generating station or from an outside source, and, this obtained, electrical rolling will be found to be considerably cheaper than steam.

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THE ELECTRIC PROPULSION OF SHIPS.

(Continued.)

It will thus be observed in connection with the "Paragon" system that at starting up the periodicity applied to the motor is comparatively low as against what it is when the motor is running at top speed; consequently the starting torque is very high, and starting resistances and other wasteful pieces of apparatus are conspicuous by their absence. The whole apparatus is alive and doing useful work. It is well known that the polyphase squirrel-cage induction motor will considerably increase its torque, together with the lowering of the speed, which is obtained in the above system, by increasing the ratio of the number of poles of the motors to that of the generator. The author has been very successful in the practical application of this principle by the use of the three-phase induction motor for operating road vehicles (motor omnibuses) in which the generator is driven by a petrol engine at constant speed, driving a four-pole alternator, and which in turn drives an induction motor having its stator wound with six poles and sixteen poles respectively. To illustrate what is meant when it is claimed that the starting torque of a given induction motor is increased when it is supplied with current that is lower in frequency at starting than that with which it is supplied when the motor is running at its normal top speed: the machinery on the above vehicle is set to work, and if the current is turned on to the six-pole winding (with the vehicle standing) there is very little if any appreciable starting torque, although a very large amount of current is circulating in the windings of both the alternator and the motor; but by changing the connections so that the current is sent into the sixteen-pole windings (4 to 1 ratio), not only is the current immediately considerably reduced, but the starting torque is enormous. For example, the author has had one of his vehicles, which weighed no less than 17,780lb. total weight, and required a tractive force of about 80lb. per ton on the level, taken on a grade of 1 in 10 on ordinary macadamised road. The vehicle, having been stopped, was started from rest by applying the current, and travelled up the gradient against the standing friction and weight as easily as could be desired. This is mentioned to dispose of the popular but misleading opinion that the induction motor is not suitable for marine work on account of its very low starting torque, which statement is perfectly true if the current be turned on to a standing motor at a periodicity equal to that at which it runs at top speed; but reduce the periodicity in some way at starting, and the torque will be very considerably increased, and to a much higher value, than will be required for any application for main marine propulsion or railway traction. This opinion is based on practical research work and practice.

A further example may be taken by the published figures of Dr. Behn-Eshenburg which appeared in the "Schweizerischen Bauzeitung," in connection with a description of a very interesting variable-speed, squirrel-cage, induction motor, which has been made by a large firm on the Continent. The dimensions of this motor do not exceed those of an ordinary motor without pole change, and it is of a type in which the speed may be changed simply by changing the connections in the stator.

The particulars given are as follows:—

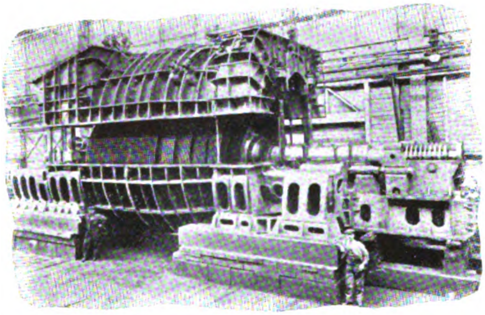

Fig. 27. One of the Low-pressure Turbines of the "Mauretania." Note the large size. If Electrical Transmission were used the Turbines would be considerably smaller for the same power produced.

Diameter of rotor D	240mm.			
Width of rotor, axially	180mm.			
Weight	220 kilos.			
Normal power	8b.h.p.			
Number of poles arranged for	12	8	6	4
Voltage	190	190	190	190
Revolutions with no load	500	750	1000	1500
Normal power	3.5	4	7	8
Normal torque	5.5	4.1	7	8
Maximum torque ..	9.5	6.2	18	12
Efficiency for full load	72%	73%	85%	86%
Efficiency for half load	70%	72%	82%	86%
Power factor, full load	0.7	0.82	0.85	0.92
Power factor, half load	0.50	0.65	0.70	0.83
Slip, full load	10%	7%	5%	4%
No-load current.. ..	11	9	8.5	6
Starting current.. ..	50	50	130	135
Starting torque	5.5	3.5	6	6
Rise in temperature after 3 hours' run ..	50° C.	50° C.	40° C.	40° C.

The motor as above designed will start against full load with the maximum number of poles switched in; the reason for this is because only one-third of the number of revolutions of the rotating field, *i.e.*, only one-third of the electro-motive forces in the armature winding, are required and exist, than with the shorter pole pitch span when the twelve poles are in circuit.

The starting against full load is done by simply switching in first the 12, then 8, then 6, and finally the 4-pole windings. No starting resistance is required, and the motor has very high starting efficiency, with high acceleration between the above operations. There is no doubt that a motor of this description will find many applications in places where the periodicity of the supply current cannot be varied to suit the starting of the motor, but in the "Paragon" system the periodicity may be varied at starting and also at the reversing period.

As regards the reversing period, it is just as well to refer to what actually takes place on an ordinary steamship driven by reciprocating engines. Assuming that the order is rung down from the bridge for an immediate reverse on the propellers, the engineer immediately shuts off steam (if he happens to be about); he then pulls over his reversing link motion gear, and admits steam. The engine does not immediately reverse—the steam simply forms a steam brake in the cylinders to the propeller, which is still revolving in the ahead direction, being drawn through the water in the ahead direction by the way on the vessel in the ahead direction, and the torque in the ahead direction becomes positive; that is to say, the propeller instead of receiving power from the engine is delivering power against it—that is, at the top of the power curve according to the high vessel speed—but as soon as the vessel reduces its speed by the resistance of the standing propeller and the resistance to speed of the hull through the water as per the previously mentioned reasons, when the torque produced in the ahead direction by the propeller falls below that of the engine in the reverse direction, the former is overcome and the

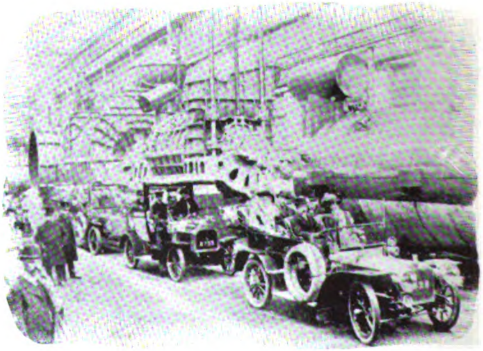

Fig. 28. A parade of Motor Cars on an inspection visit round the works where the Main Turbines of the "Mauretania" were made (shown in the background).

propeller immediately starts to reverse, increasing in reverse speed as the vessel speed comes down, to a point when the vessel stops, and then the vessel reverse speed direction takes place, and acceleration in the reverse vessel speed attained.

We will now just look into what will take place in the vessel that is fitted with the "Paragon" system of electrical driving Assuming the vessel is proceeding at full vessel speed, and the navigating officer wishes for some reason to bring about an immediate reverse in the vessel speed direction, he breaks the excitation circuit of the alternator, and the whole system is in an immediate no-voltage condition. The propellers, however, still turn in the ahead direction, and the rotors will also be turning in the ahead direction, being driven by the propellers mechanically as above. Now he immediately (while the system is under the no-voltage condition) connects the motor stators with the low periodicity terminals of the generator, but into reverse direction for the flux in the stators of the motors, and then by again closing the excitation current on to the generator, the three-phase current revolves in the counter direction to that of the rotors. The latter therefore become asynchronous generators, being driven in the reverse direction by the propellers, and immediately become very powerful brakes to the propellers, that condition remaining until the vessel drops in speed in the ahead direction, when the high-starting torque produced by the low periodicity current in the stator in the reverse direction will revolve the rotors in the astern direction similar in action to the steam engine as above described, the electric operation taking less time than in the case of the steam engine, especially if the steam engine happens to be of a multi-cylinder type. Whereas the starting torque is limited in some cases to that which is produced by the action of the steam pressure on say the high-pressure cylinder piston, the reverse torque being on the outside periphery of the rotors of the motors, the stresses and strains of reversing will not be felt on the machinery to such an extent as with the reversing of crank-shaft steam engines. The current generated in the windings of the stator and circulating in the circuits between the generator cannot accelerate in periodicity as the vessel speed is falling all the time, and it is on for such a short period that the heating effect of such current may be negligible.

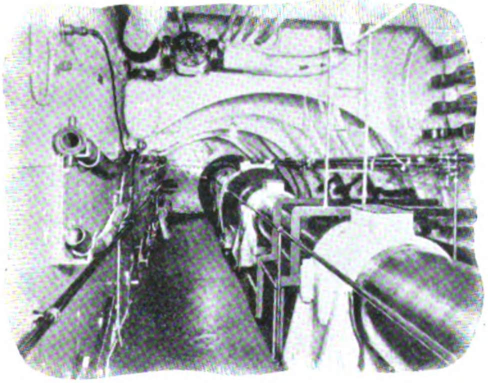

FIG. 29. SHAFT TUNNEL OF ONE OF THE FOUR SHAFTS OF THE "MAURETANIA." A CONSIDERABLE SPACE IN THIS MOST IMPORTANT PART OF THE VESSEL WOULD BE SAVED IF ELECTRICAL POWER TRANSMISSION WERE USED.

FIG. 30. THESE ARE FUNNELS, NOT TUNNELS.

With the possibility of control from the bridge, not only will time be saved, but greater certainty of operation may be attained owing to the absence of the transmission and reading of signals, &c.

Having now referred to the possibilities of the application of the high-speed steam turbine for main marine propulsion in conjunction with the "Paragon" or other

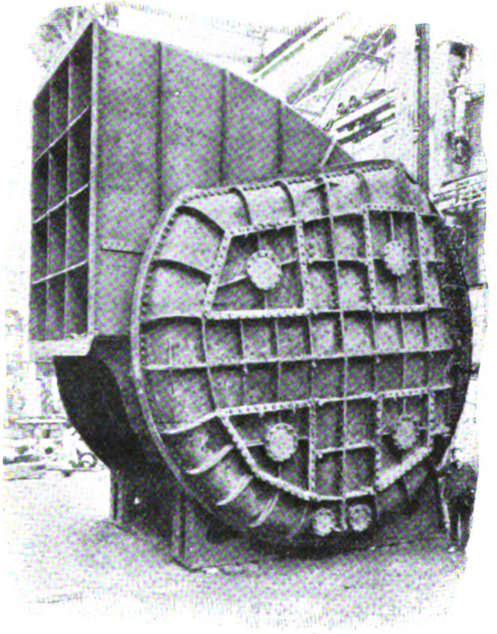

Fig. 31. One of the two Main Condensers used on the "Mauretania." Owing to the less amount of steam required in the Electrical Power Transmission for Main Marine Propulsion, such items would be considerably reduced in size and also in cost and weight.

electrical systems, in which it may be observed that the use of high superheated steam becomes possible owing to the small diameter of the turbines, which factor is not effected to the extent that the existing large-diameter, slow-speed, direct-coupled turbines would be, it will be seen very readily that the application of electrical power transmission and speed regulation offers tremendous advantages commercially and otherwise by its utilisation on steam vessels as above indicated.

There is, however, another large field of utility for the application of electrical power transmission which is very rapidly coming to the fore, *i.e.*, the application of internal-combustion engines for marine propulsion, which is a subject forcing the attention of not only internal-combustion engine designers, but also the naval architect and the marine engineer.

Gas and oil engines offer such tremendous advantages over steam engines and turbines that a reference to some of them will not be out of place before describing the reasons why, in the author's opinion, they have not been more generally applied in large powers for this important purpose.

Some of the great advantages that are embodied in the proposition of the utilisation of the internal-combustion engine at sea are as follows:—

1. The thermo-mechanical efficiency is higher per lb. of coal or other fuel burnt, meaning that the number of horse-power hours per ton of fuel carried is higher, as, for instance, the radius of travel of the vessel is increased at the same vessel speed by about 40 per cent.

2. The weight of the machinery per horse-power developed is lower, as, for instance, the weight of the machinery of a steam vessel with water-tube boilers can be put down at about 10.1 indicated h.p. per ton (including water in the boilers), while the total weight per indicated h.p. in a suction gas-engined vessel may be put down at 14.48, or is equal to an increase in h.p. per ton of dead weight of about 43 per cent. as compared with the above steamship machinery weight (including water in jackets and piping, but not coal in producers);

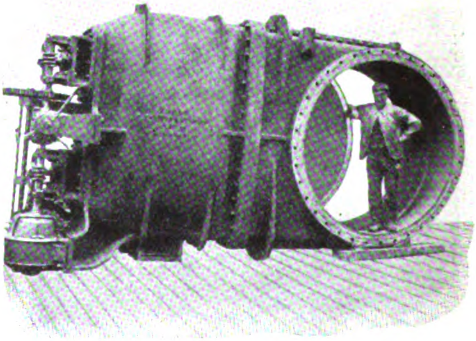

Fig. 32. One of the Motor-operated Main Exhaust Valves of the "Mauretania." In the Electrical Transmission of Power for Main Marine Propulsion such Valves would be much smaller, and also much lighter, &c.

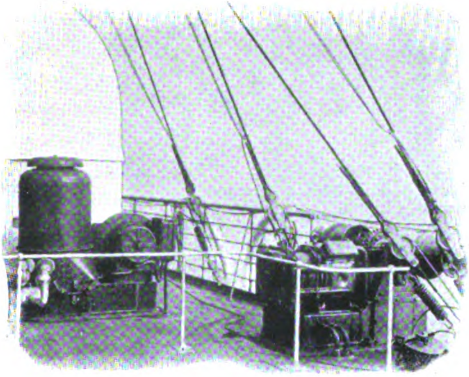

FIG. 33. ELECTRICALLY-OPERATED WINDLASSES ON THE DECK OF THE "MAURETANIA." SUCH METHOD OF DRIVING THESE AUXILIARIES IS BECOMING VERY POPULAR.

whilst with the internal-combustion engine using oil direct instead of coal in producers, the indicated h.p. is equal to 21.33 per ton of weight, and is a saving of no less than 47 per cent. on the gas-engined ship. (The above figures are the comparisons of a 16,000h.p. ship.)

3. The absence of funnels and other equipment in internal combustion engined vessels reduces the resistance by wind and other causes, and the vessel can under those circumstances maintain better stability, &c., whilst in the case of ships of war the non-existence of these top impedimenta is a self-evident advantage.

4. In the case of the gas ship the coal-bunker space occupied by the fuel is less, and the time for coaling, &c., is materially reduced; and in the case of the oil vessel the fuel can be handled by pumps, &c., and not by hand, which is an enormous advantage in many directions, and, above all, takes less time, is quite silent in working, and can be packed in closer space.

5. The internal-combustion engine is always ready to start, and the working costs approximately start and stop with the running of the engine.

There are many reasons why very close attention should be given to the possibilities of the internal-combustion engine in this sphere of action, and no doubt the near future will witness some startling change in this direction. Increasing popularity of this very efficient prime-mover for marine work is inevitable especially for use with vessels of moderate power. It is, however, of more than passing interest to consider why the internal-combustion engine has not up to quite recently become more attractive as a sound proposition for main marine propulsion, and a few of the disadvantages that exist with most internal-combustion engines may be briefly put as follows:—

1. The thermal efficiency falls rapidly at lower revolution speeds than represented when on full load (see Fig. 37).

2. There are conditions to be met with in reversing a propeller that the thermal-dynamic principles of the internal-combustion engine are not suited for (especially in the four-cycle type), for reasons that have been described previously in this article in connection with the working of steam engines when reversing, &c.

3. The internal-combustion engine is better adjusted for always running in one direction, as the most efficient point of ignition is variable according to the speed at which the engine may be running at all times. This is especially the case with marine multi-cylinder engines. If the times of ignition are not in synchronism, that is to say, if the exact time of ignition is not the same at each cylinder, the exact moment of ignition being later or earlier in some of the cylinders, the result of this non-synchronism is noticeable in the fact that not so much actual work is got out of a given amount of fuel, and also the engine will not run so well under those conditions, the explosions being unequal in each cylinder as regards pressure. The effect of this is that an engine in this condition will run out of balance (although it may be immediately stopped and tested for mechanical balance and found correct, yet it will run out of balance as soon as put on to work again, as the out-of-balance is caused by the unequal explosions that are taking place when under work). Now if the same engine be arranged to run in one direction only, and the time of ignition adjusted so

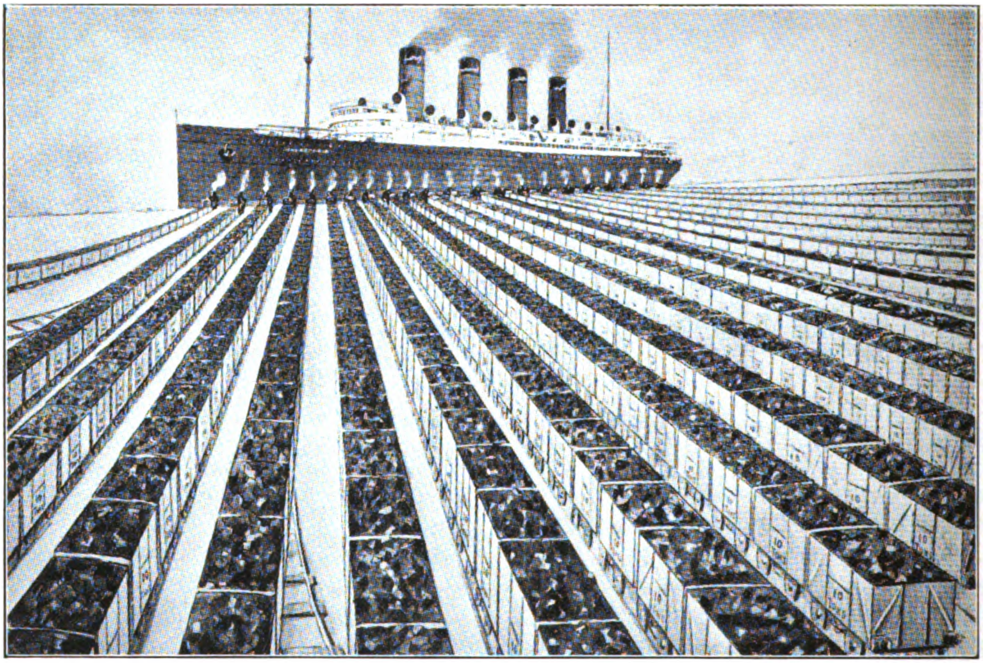

FIG. 34. THE COAL SUPPLY FOR ONE VOYAGE OF THE "MAURETANIA" AMOUNTS TO NO LESS THAN 6600 TONS.

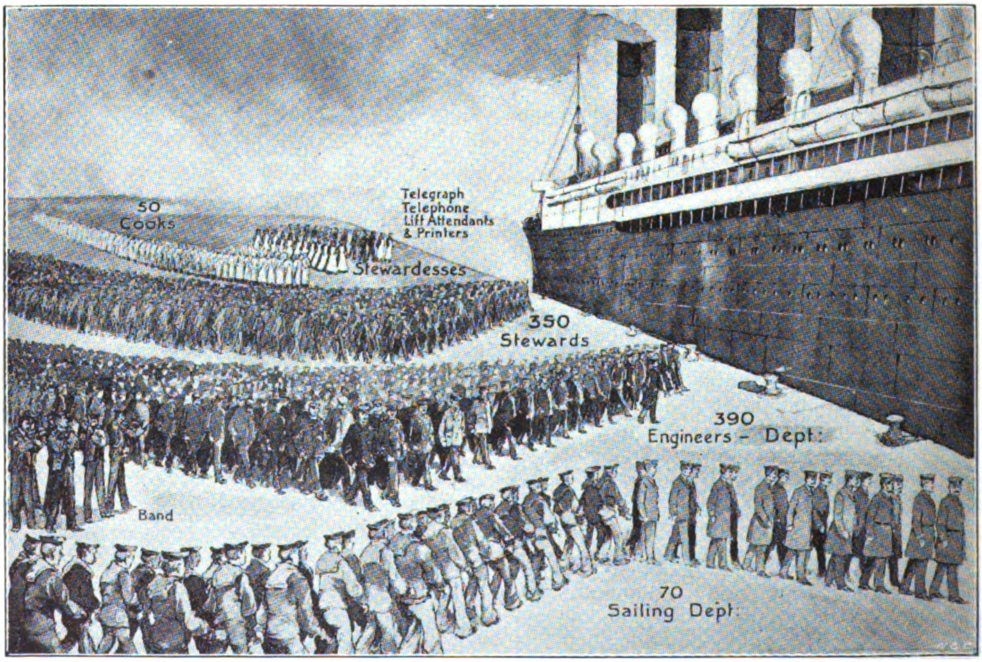

FIG. 35. ILLUSTRATING THE STAFF CARRIED BY THE "MAURETANIA."

that it is always in synchronism, and the engine run at one speed, then not only will it run more steadily but the fuel consumption will be found to be lower for a given amount of work done. Further, the explosion taking place at the early part of the stroke, the expansion is much more efficient, and the consequent exhaust gases pass to the exhaust box at lower pressure and temperature, resulting in quiet operation and better utilisation of the heat from the fuel. It will be found in practice that the wear and tear, under the above correct conditions, on the exhaust valve gear, &c., will be almost conspicuous by absence, a point that is not of little importance when considering the application of internal-combustion engines for main marine propulsion, where continuous runs lasting sometimes for weeks at a stretch are normally taking place. Theoretically the proper time for igniting the charge is at the end of the compression stroke, when the compression is at the highest, for this would mean the best mechanical result. But "igniting" and "exploding" are not the same thing, because when the ignition occurs (on a high-speed engine) its effect is only felt in the immediate neighbourhood of the ignition. The flame then spreads as an explosion wave through the rest of the mixture. This spreading takes *time*, and although the time is short it must be remembered that the piston speed is high, there is a brief interval between the ignition and the full force of the explosion (and this varies according to the intensity of the ignition and the piston speed in all explosion types of internal-combustion engines). Therefore it is quite certain that to get the full effect of the compressed mixture, the ignition must take place slightly before the end of the compression stroke. So much for the important (as regards economical fuel consumption) matter of ignition.

Under similar conditions the valve-gear, both admission and exhaust, must be adjustable, and in some high-speed internal-combustion engines, in order to get the highest thermal mechanical efficiency out of them, the valves are set as follows: the admission valve is set to open *late* by about 3deg. or 4deg., and to close about 10deg. to 12deg. *late*; on the other hand the exhaust valve is set to open about 20deg. to 30deg. *early*, and to close about 3deg. to 4deg. *late*, according to the speed at which the engine is designed to run when working at full load when the highest efficiency is naturally required.

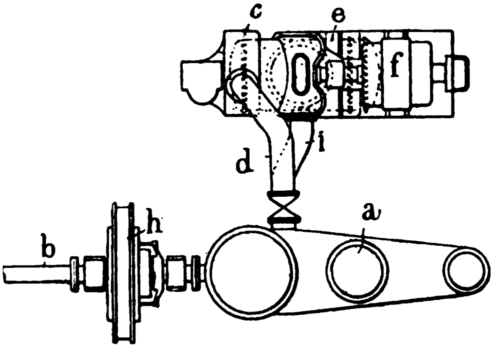

Fig. 36. A proposal to introduce Electrical Transmission of Power in connection with the ordinary Reciprocating Steam Engine, and also the use of high-speed, low-pressure, Exhaust Steam Turbines with Dynamo and Motor on the Engine and Propeller Shaft. This may, in some cases, be a very efficient method, especially in converting existing vessels.

Further, it may have been observed by the reader that it will be a very difficult matter to make a satisfactory (from both mechanical and thermal efficiency points of view) reversing marine gas or other internal-combustion engine, and it has even been proved by the most accurate and scientific research work and experiment that in order to get the very best results out of the internal-combustion engine, it must always run in the same direction and at constant speed and have its cylinders offset from the centre line of the crank-shaft, *i.e.*, so that when the end of the compression stroke is reached, the centre of the cylinder is in advance of the centre line of the crank-shaft. The result is that when the explosion occurs the crank-pin is past the dead centre of the crank-shaft, and the very large angular static pressure that would exist between the piston and the sides of the cylinder walls is very greatly

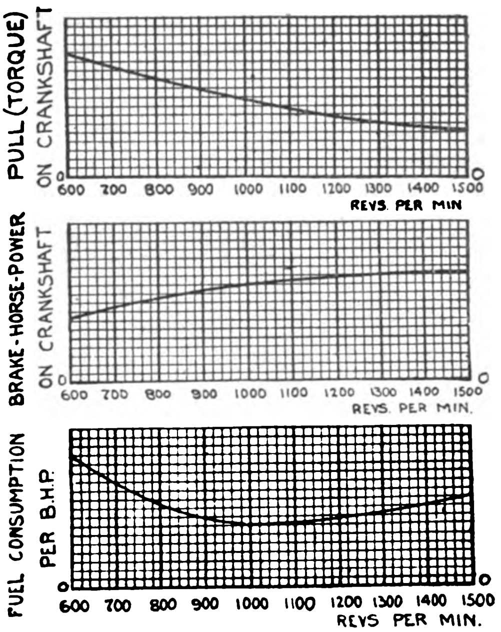

Fig. 37. Typical Curves indicating the approximate manner in which the "pull," the "horse-power" and the "fuel" efficiencies of an ordinary Petrol Engine vary at different speeds. Speeds from 600 to 1500r.p.m. are represented.

reduced. All first-class-design internal-combustion engines are built on the lines indicated with the object of reducing shock and vibration by thus giving a direct thrust on the moving crank on its downward stroke. This is a most successful item in design, and it is also obvious that the embodiment of this very necessary principle precludes the design of a reversing marine internal-combustion engine on these lines, due to the complication that would exist in such a method of adjustment to get the maximum of all-round efficiency, which economy is absolutely necessary, and is most desirable in successful marine engineering. Simplicity must be considered and also low cost of manufacture, together with reliable and *safe* working at sea.

There are several other methods of reversing the marine internal-combustion engine, but the author believes that he has pointed out sufficient to enable the reader to grasp the meaning of this rather lengthy description; and it is this—that it is not possible to make a satisfactory reversing marine internal-combustion engine, and that it is very evident that other and much more efficient methods must be used, before the marine internal-combustion engine can be accepted as a sound commercial proposition.

It is therefore evident that reversing, changing the propeller speed, and all the other operating conditions, must be obtained by some other method, and it is of the greatest interest to note the highly important position that the electrical transmission of power for the above purposes holds.

It has been suggested at various times that such desirable things might be brought about by the use of change-speed mechanical gear, and this has been tried with some success on small power boats, with petrol and other engines; but when it comes to dealing with large powers the proposition of mechanical gears is out of the question, not only owing to the fact that the noise and the rattle and the wear and tear of teeth, &c., would be prohibitive, but also to the fact that in order to always keep the prime mover running at one constant speed, some kind of change-speed gear would have to be provided for slowing and reversing the propeller. Not only would such gear be out of place, but the apparatus would also necessitate some sort of slipping clutch in order to allow the gentle application of the power of the prime mover to the propeller, especially on reversing.

In order to meet the above requirements various other suggestions have been made, introducing several mediums, such as compressed air and hydraulic power transmission. Although compressed air has been extensively used in small powers, it involves apparatus of such large dimensions that it would require the space of ordinary marine reciprocating engines to utilise the energy for driving the slow-speed propellers, and for that reason alone could not be considered as a practical solution; furthermore, it would entail considerable losses in many directions from a thermal and mechanical point of view owing to the high compression that would be necessary in such an application. Hydraulic gear would be a very interesting proposition, but it is questionable if reasonable mechanical transmission efficiency could be secured and vibration avoided. Owing to sliding parts, &c., wear and tear would in very large powers become very pronounced, and, furthermore, either of the two above-mentioned systems of power transmission would not secure the utmost propulsive efficiency for a given amount of steam power, especially in rough weather, as illustrated on page 182, Fig. 22 (ELECTRICAL MAGAZINE, April), which shows a vessel under rolling conditions, and in which state the propulsive efficiency is bound to fall, owing to the unequal depth of immersion of the propellers, in, say, a twin-screw boat.

The author witnessed some very interesting tests in this respect recently, and on a vessel which was fitted with ordinary reciprocating engines, which were designed to normally run at a speed of 100r.p.m. on even keel, the vessel under the rough-weather conditions rolled to an extent of about 10deg. to 12deg. from the vertical, and the engines correspondingly ran as follows: the more deeply immersed propeller engine slowed to about 80r.p.m., whilst the engine driving the lightly immersed propeller rose in speed to about 130r.p.m. Both engines, therefore, wasted steam for the following reasons: the one that was driving the lightly immersed propeller used steam to accelerate in speed its heavy reciprocating parts, and the other engine took a full steam stroke instead of an expansive one. The propulsive efficiency of the propellers fell for these reasons: the lightly immersed one, through the increased speed, and owing to the fact that cavitation sets in; whereas in the case of the deep propeller, owing to the pitch of same being constant, and the revolutions having fallen, the volume of water displaced is less, and consequently the total effective thrust on the ship is materially reduced. The distance travelled by the vessel per ton of coal burnt must be therefore reduced under the above conditions. If the steam pressure could automatically be increased in the cylinders of the deeply immersed propeller engine, and likewise decreased in the cylinders of the lightly immersed propeller engine, the over-all propulsive efficiency of the steam used would remain practically constant because the speed of each engine would have remained practically constant under the varying load conditions.

Now it is interesting to note what would take place under similar rolling conditions on the vessel that would have its propellers driven by polyphase alternating-current induction motors, supplied from turbo or gas-driven alternators, the speed of which remains constant. The lightly immersed propeller cannot race, but takes less current from the generating plant; whilst the deeply immersed propeller does not slow, but takes the current from the generating plant that the lightly immersed propeller motor does not require. In fact the current is constantly surging to and fro between the motors as the load on each momentarily varies. The consequent load on the generating plant remains practically constant, utilising the steam to the maximum advantage and improving the propulsive efficiency per ton of fuel burnt. The above is not the least important effect of the application of electrical power transmission with polyphase alternating current with induction motors for propeller shaft driving, and it is very doubtful if such efficiency could possibly be obtained by any other method.

WILLIAM P. DURTNALL,
M.I.Mar.E., M.I.Auto.E.

(*To be continued.*)

THE WORLD'S ELECTRIC PROGRESS.

Paris Subway Work.

PARIS is rapidly coming into the lead in the matter of electric subway systems, and within a few years, when the present programme is carried out, it will possess no less than sixty miles of subway, covering all parts of the city, so that it will have much the best rapid-transit facilities of any of the largest cities of the Continent. We wish to refer here to some of the new construction work, which presents considerable interest. It will be remembered that in Paris there are several methods used for the metropolitan lines. An underground tunnel for double-track trains on the third-rail system is the prevailing type, and in some sections there is used an elevated construction mounted upon iron columns. Two iron bridges were built specially for the elevated sections, and in another case an existing stone bridge was modified for the purpose. In some sections the line changes frequently from subway tunnel to elevated line.

There are three lines building at present which are obliged to cross the Seine in tunnel, seeing that bridges were not allowed. Two of these lines use a tunnel in the Seine bed which is laid from the surface by means of metallic caissons. This tunnel accommodates the double track, and is somewhat elliptical in section ; under the river it takes the form of an iron tube built up of curved pieces or voussoirs. A certain length of tube is thus built into a metallic caisson, and the whole is sunk in the bed of the Seine. One of the largest pieces of caisson work yet carried out in Europe was the sinking of the stations in the City Island between the above-mentioned tubes and another at the St. Michel Place on the south bank. The latter station is made up of three separate caissons, the middle one containing the station platforms and having an elliptical section, while at each end there is a large structure in the form of an elliptical well sunk in the ground. These are used for the approaches, and contain the staircases and ticket offices. These three caissons form an immense mass containing 12,000 tons of iron and cement, and make a station of nearly 400ft. length. All has now been sunk to the same level as the Seine tunnels. Counting the whole work in the Seine section there is a 0.65 mile length.

Another piece of work of a different character is the double-tube tunnel further down the Seine, known as the Berlier tube, and it serves for a different subway line. Two tubes, each having a single track, are used here. Starting from an underground station on the bank of the Seine, the two tubes of 16ft. diameter proceed in a nearly parallel direction, running under the Seine and coming together in a second underground station, the tube portion covering 1800ft. length. The tube is run under the Seine by means of the compressed-air shield system. The underground station at the start of the tunnel contains over 1000h.p. in electric motor-driven air compressors for carrying out the work in the tubes.

Railway Electrification.

THE prelimininary trials of the L.B. & S.C. Railway Company's suburban electric train service have been carried out with complete success, but only the section from Victoria to Peckham Rye is complete. Regular running will shortly begin on this section, but the remaining stretch from Peckham to London Bridge will not be completed for another two or three months.

When the service is complete at least eleven minutes will be saved between the two termini, and a more frequent service will be available. The "Electrical Review," in giving some particulars, states that the current per train will only be between 100amp. and 140amp. at the line voltage (6700 volts), and the circuit breaker need in no case be set at much above 500amp. to 600amp. Assuming that it is set at 600amp. there may be a momentary expenditure of about 4000k.v.a. before the breaker comes out, and supposing the current-phase displacement to be 45deg. or thereabouts the actual energy momentarily expended at the generating station will be about 5000kw. This is a formidable figure and draws attention to the heavy stresses which generators and transformers alike have to withstand. On the Hamburg-Blankenese Railway, which has recently completed its first year's working, it was found necessary for this reason to re-secure the coils in both generators and transformers.

On short distance lines with frequent service and many stops, not only is there a reduction in the coal bill possible by electrification, but the repair and maintenance of locomotives costs less, and the repairs can be done so much more quickly that it is unnecessary to provide as many electric locomotives as is the case if steam-driven engines are used. It is estimated that on a main-line railway 36 per cent. fewer locomotives would be required by adopting electric traction. On the other hand, Mr. Philip Dawson points out in an article in the "Electrical Review," that the long-distance non-stop trains in this country will always be more cheaply driven by steam. In countries where there is plenty of water power available for generating purposes the case is different. Thus the Swiss Government have just decided to commence the work of electrifying the main line section, Spiez-Frutigen, with the ultimate intention of converting the whole of their railways. Very extensive works of a like nature are contemplated in South Germany. There is general agreement among experts that single-phase high-tension overhead transmission, with low periodicity, is best for this class of work. The Spiez-Frutigen section will be worked with 15,000 volts at only fifteen periods, or nearly two and a half times the pressure of the Brighton system. There will be motor carriages for passenger trains and locomotives for goods traffic. The former will at first be fitted with two and ultimately with four 220h.p. motors. This heavy equipment is required to meet a gradient of 1 in 37 on the Lötschberg section, which will be added later. The complete motor carriage will weigh 55 tons and will draw a total train weight of 160 tons (including its own weight) up a gradient of 1 in 37 at a speed of 28m.p.h. Two different locomotives have been ordered; these will run on two pivoted three-axle bogies. One of these locomotives will have a 1000h.p. motor on each bogie and the drive will be transmitted through gear wheels and cranks to all three axles; it will be the most powerful single-phase engine yet built, and will weigh 86 tons, the whole of the weight being available for adhesion. This engine will draw a train weighing 310 tons up a gradient of 1 in 37 at 26m.p.h. The other locomotive will be of a slightly less powerful type and will only have one driving axle on each bogie. The two types have been ordered with a view to determining which is most suitable for main line work in Switzerland. The maximum speed required will be about 43m.p.h.

* * *

Improved Induction Furnace.

An improved type of electric furnace due to Heilberger is described in the "Zeitschrift für Electro-Chemie." This is an induction furnace with double transformation. The first transformer has an ordinary rectangular core; on one limb is wound the primary, consisting of well-insulated copper wire which carries the high-tension current; on the other limb is placed the secondary, consisting of a few turns of stout copper tube of the requisite section. This tubular conductor is carried on to form the primary coil on the core of the second transformer, the secondary of which is a single turn formed by the trough of metal which is to be heated. Cooling water is circulated through the two tubular windings, which are air-insulated. The core of the second transformer is a deep ring of rectangular cross-section, and it is carried on rollers which are mechanically rotated, and slowly turn the core on its own axis. In this way every part of the core is in turn cooled by being passed through the water-cooled coil of the primary ; this enables the core, which is linked with the trough of molten metal, to be kept at a reasonable temperature. The first transformer remains comparatively cool, so that the rapid deterioration of the insulation of the high-tension winding is prevented.

Mr. Ferranti has designed a similar induction furnace, but with single transformation. The core is a large ring of rectangular cross-section, with a diametral limb. The primary is a tubular water-cooled coil, and the secondary is formed by the ring trough of the furnace ; both coils are linked round the middle limb, and are embraced by the annular portion of the core. This arrangement makes a very efficient magnetic circuit.

* * *

A Flying Substation.

THE "Industrie Electrique" gives an account of a portable or flying substation recently built by Ganz & Co. for the Valtellina line in Italy. The whole gear is contained in a closed iron wagon, which is internally divided into two unequal compartments by an iron partition. The operator is unable to obtain access to the larger section while it is under pressure. The apparatus comprises a 130k.v.a. fan-cooled transformer, two 20,000-volt, three-pole oil switches—one with automatic trip gear, and one hand-operated ; two sets of three double-pole 3000-volt oil switches—one set automatic and one set worked by hand. A Wurtz lightning arrester, with special choking coils, completes the high-tension outfit, except for the line connections fitted to the roof of the car and suitably insulated. The operator's cabin contains the handles for the non-automatic switches, instruments, pilot lamps and warning bells ; both the latter indicate when a circuit has been opened automatically, and show which line is affected. There are three sets of 3000-volt switches, because when the car is stationed at Colico, there are the three lines to Chiavenna, to Sondrio, and to Lecco, requiring separate control. At the other stations only two sets are needed. This substation is used to take the place of one of the others while they are under repair, or to boost up the line pressure at any point where the traffic may be exceptionally heavy.

* * *

Lamp Manufacture in Germany.

A CORRESPONDENT in Germany sends us some interesting remarks anent the present trade conditions and business methods of "the illuminating industry" of that country. He refers to the attention which makers of incandescent mantles have been receiving, their affairs being discussed generally and not only in the concerned circles. This unusual interest was caused by the extraordinary rise in value of the shares of the largest firm in the trade, the Auer Company. In the old days when the value of these shares stood at about 1000, a wild transport of joy overcame the majority of the gas experts. Many competing companies were founded for the purpose of making mantles, but most of them did not succeed, and many became bankrupt. It is, therefore, improbable that the example of the Auer Company will induce an expert or capitalist to open a similar establishment. Times have changed in lighting practice, and it would seem indisputable that the present favourable situation of this large German firm is nothing else but the result of a sound natural development. The laymen often overlook that this enterprise is no longer confined to the incandescent gas mantle industry, and that they have been wise in time and extended their business to include an electric lamp department. This latter department has now passed the experimental years and works side by side with a gas department destined to give way more and more to the advance of the electrical side of the business. In the last year for instance the profit was about double that of 1907 in the electrical branch, and a dividend of 35 per cent. could be distributed.

It would appear, however, that the satisfactory condition of the Auer Company is exceptional. If one considers the general situation of the other German firms, one receives a very different impression. There was a general economical depression during the past year affecting practically all German industries, and that of lamp manufacture was not excepted. The success of one single firm, which in those unhappy times was fortunate enough to turn out a new article for which there was a great demand, does not alter the above fact. For the incandescent gas mantle industry proper during the year 1908 was by no means a good one. The still existing stagnation is, according to our correspondent, to be explained by the uncertainty as regards the intended action of the Government which proposed a tax for any kind of lighting. Under such conditions a powerful development is not possible. This unsettled feeling is especially a burden for the inland market. While the manufacturer uses a certain caution when purchasing the necessary raw material, the wholesaler as buyer of the finished product will not enter into the customary yearly contracts where large sums are in question. More than ever before the demand will be filled from hand to mouth, or by small and frequent purchases instead of business deals closed for a long period.

It is, perhaps, not generally known that the greater number of German lamp manufacturers and wholesalers founded a society about fifteen months ago to promote the welfare of this industry. Already this association has made itself felt, for after protracted and somewhat exciting fights with certain syndicates, the society fixed standard prices according to the manufactured and sold quantities. They have thus furthered not only their own branch but also that of the glass industry for lighting purposes, the textile works for wick, and the smaller foundries, but particularly the retailers. The league has a great power, but they have not utilized it for keeping down the prices unwarrantably, and to obtain unusually favourable conditions. It is the duty of the members not to buy from outsiders. The society extends over the whole German Empire, and at present sixty-six of the largest lamp manufacturers have joined it. Every year there is one Congress, besides smaller meetings.

Our correspondent goes on to say that every kind of union in business life is a source of power and makes for economy. Industrial and commercial development more or less calls for concentration in most fields of human activity. Where formerly was sharp competition now there is harmonious working together. Guided by such considerations, and by the good results attained in other industries, a number of German firms of electric specialities proposes towards the end of the present year to arrange collective exhibitions of their products at regular intervals on the world-famous "Leipziger Messe." As is done in many other branches, all novelties and improvements of electrical manufacture are to be demonstrated in a modern and practically constructed exhibition hall before the great international circle of buyers and other interested parties, who meet year after year twice in Leipzig, at Easter and in the autumn. The results of such a combination regarding time and place of demand and offer in electric products will be advantageous to the exhibitor as well as the buyer. For the latter, whether he is wholesaler or exporter, such an exhibition is an excellent medium of information about prices, demand, and the direction of production, of personal contact and talk with the manufacturer, of correct choice and economic filling of one's demand. The exhibitors again will profit by the enormous number of the buying public who come from far beyond the German borders. Last year every Leipzig "Messe," or market, was attended by 1300 inland firms and 210 foreigners, which number will now be increased owing to the above action of the electrical firms. Through the combination of the latter the exhibitors will save in time, rent, attendance, advertisements, posters, use of current, &c. By putting together all samples of the illuminating industry which before were scattered in different buildings over the whole market quarter in Leipzig, a rational utilization of time for exhibitor and buyer is made possible, and profitable business guaranteed. This concentration permits a general propaganda on a large scale at home and abroad.

* * *

"Elektro-Spar" Lamp.

A NEW device has been brought out in Germany called the "Elektro-Spar" Lamp. This consists of a somewhat enlarged lampholder containing a small transformer, which transformer steps down the usual supply pressure to a low voltage suitable for metallic-filament lamps with short thick filaments. The arrangement is of course only suitable for an alternating-current supply. The chief advantages are: (1) the lamp lasts longer and there is less breakage in transit owing to the short, thick filament; (2) low candle powers are available at high supply pressures; (3) there is no light load loss on the transformer, because it forms part of the lamp and is therefore switched off with it. The transformer, which is of the cylindrical core type, is very efficient, the following results having been obtained on test.

On a 220-volt supply stepped down to 7 volts an 18c.p. lamp takes 1.5amp. = 0.6 watts per c.p. Other figures obtained are 8c.p. lamp 7 watts; 16c.p. lamp 12 watts; 32c.p. lamp 24 watts.

The enlargement of the lampholder makes very little difference in the appearance of the fittings, and the details of the lamp are so far advanced that the holders are about to be manufactured on a commercial scale.

* * *

A High-tension Detector.

A DEVICE has lately been introduced which will be found of service by the central-station engineer who has to do with high-pressure plant and networks. The high-tension detector is a handy instrument convenient to bring into service at any time, and as such will commend itself. It gives an immediate indication of whether a conductor is "alive" or not, and consists essentially of an exhausted glass tube with an interior and an exterior electrode. The air has been rarefied to such a degree that the tube lights up brightly at tensions of 1200 to 20,000 volts. The vacuum tube is enclosed in another glass tube, and the latter again in an ebonite tube with a slot, through which the light may be observed. At one end the tube is covered by a metal cap ending in a point, at the other by a metal socket, to which a long ebonite handle is attached. A flexible conductor is also connected to the socket. In order to determine if a conductor is charged with a high-tension current, the flexible wire is connected to the ground and the pointed cap brought in contact with the conductor.

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TESTS OF THE EFFICIENCY OF A WARMING PLANT.

WHILE plenty of information is available as to the rate of transmission of heat through radiators heated by hot water, there appears to be very little published concerning the efficiency of complete warming plants. This article deals with the results obtained on testing a complete plant, and it is believed that some of the quantities have never been previously determined.

The plant was installed in the Nurses Home of the Hospital for Sick Children by Messrs. Burn Bros. under the direction of the consulting engineer, Mr. C. T. Walrond, A.M.I.C.E., and the author is indebted to his clients, Messrs. Burn Bros., for kindly allowing him to publish the results of the tests.

The plant tested consisted of a heater, the copper coils of which were supplied with live steam. The hot water was forced round the system by a duplex steam pump and the radiators were of the ordinary type. The plant had been in ordinary use for four months (February to May) before the tests, consequently the steam coils in the heater were incrusted with scale, which, at the end of the first trial, was found to be $\frac{1}{30}$in. in thickness.

Owing to the construction of the corridors which were warmed by the apparatus, and to the fact that the building was in constant use by the nurses, it was impossible to include all the radiators in the trial, but to compensate partly for this extra radiators to the extent of 88sq. ft. were placed in the dining room, which previously had only 54sq. ft. of radiator surface in it. These, together with the naked pipes connecting up the radiators, gave a total surface of 236sq. ft.

The dining room was 23ft. by 28ft. by 10ft. high and was in the basement of the building, though its floor was on a level with the ground line at the back of the hospital. It was fitted with three ordinary sash windows, each being 3ft. 8in. wide by 5ft. 6in. high (net dimensions of glass).

Its walls were brick, 27in. thick. One and a half of the longer walls, and the wall at the north end of the room, were external walls. Owing to the fact that in the first trial the heater was not working at its full capacity (for the reasons previously stated, and also on account of the atmospheric temperature), it is probable that the efficiency of the combined plant was lower than it is when all the radiators are in use. Another important fact to be borne in mind is that the dining room in which the radiators were placed was 294ft. from the boiler house and heater. This undoubtedly militated against the efficiency of the system as a whole, though the 1½in. flow and return pipes were lagged with 1in. of magnesium carbonate insulating material in "sectional" form.

The exhaust steam from the circulating pump was not passed through the heater, and this quantity of steam has not been included in the thermal deductions, but has been included in the estimate of the cost of warming by a forced circulation of hot water.

The heater and circulating pump were started at noon, whereas the first trial did not begin till 3.30 p.m., so that there was plenty of time for the pipes, radiators, and walls to get warmed up to a constant temperature.

TRIAL NO. 1.

Duration of the trial	2.50 hours
Mean temperature of flow water at the heater	211.5° F.
Mean temperature of return water at the heater	194.4° F.
Difference ...	17.1° F.
Mean temperature of the flow water at the dining room ...	206.0° F.
Mean temperature of the return water at the dining room ...	196.0° F.
Difference ...	10.0° F.
Mean temperature of the air surrounding the first 200ft. run of the flow and return pipes from the heater to the dining room	86.9° F.
Ditto ditto of the remaining 94ft.	66.1° F.
Total quantity of water circulated through the heater ...	13,560lb.
Mean pressure above atmosphere of the steam supplied to the heater	14.3lb. sq. in.
Total quantity of steam passed through the heaters	275.5lb.
Ditto ditto used for the circulating pump	183.2lb.
Total quantity of air passed through the dining room ... (Equal to 4.12 changes per hr.)	66,205 c.ft.
Mean temperature of the air entering the room	68.9° F.
Ditto ditto leaving the room	93.8 F.
Difference ...	24.9° F.
Total quantity of heat given to the air...	29,425B.T.U.
Ditto ditto lost by the water in the room	135,600B.T.U.
Total quantity of radiating surface in the room	236sq. ft.
Rate of transmission of heat per sq. ft. of radiating surface	230B.T.U. per hour
Rate of transmission of heat per sq. ft. of radiating surface per ° F. difference of temperature between the radiator and the air in the room	1.92B.T.U. per hour
Rate of transmission of heat per sq. ft. of surface of coil in the heater	4,075B.T.U. per hour
Ditto ditto per ° F. difference of temperature between the steam and the water	151.8B.T.U. per hour
Total heat given to the air ÷ total heat discharged from the radiators	= 21.7 %
Hence: Total heat radiated through walls and windows ÷ total heat discharged from the radiators	= 78.3 %
Total heat given to the air of the room ÷ total available heat of steam supplied to heater	= 10.7 %
Total heat radiated through walls and windows ÷ total available heat of steam supplied to heater	= 38.7 %

The sum of the last two quantities gives the :—

Efficiency of the system ...	= 49.4 %

This is the same thing as :—

Total quantity of heat discharged into the room by the radiators ÷ total available heat of the steam supplied to the heater	= 49.4 %
Total heat delivered into the room ÷ total heat sent out from the heater	= 58.6 %

Total heat lost in transit from the heater to the room ÷ total heat sent out from heater ...	= 41.4%
Efficiency of heater = total heat given to the water ÷ total available heat of steam used	= 84.5%
Mean rate of loss of heat per sq. ft. of external surface of the non-conducting material on the 1½in. flow and return pipes (each 294ft. long) per ° F. difference of temperature between the hot water and the air surrounding the pipes	0.58B.T.U. per hour
Velocity of the water in the flow and return pipes	2ft. per sec.

In studying these results, perhaps the most striking is the smallness of the percentage of the available heat of the steam supplied to the heater which appears in the air of the room—namely, only 10.7 per cent.

A careful search and numerous inquiries for corresponding particulars of other trials were made, but without result, except the value 28.9 per cent. This however was not obtained directly, but was deduced from some results obtained under somewhat similar conditions by Prof. R. C. Carpenter in America. In his experiments, however, the radiators were not in the rooms, but these were supplied with hot air from a central heater chamber in the midst of the building, while in my trials the heater was 294ft. away from the room. Hence, whereas only 61 per cent. of the heat discharged into the rooms was radiated into the walls in the case cited, 78.3 per cent. was so radiated in my case. The remaining 21.7 per cent. of the heat in the latter case, and the 39.0 per cent. in the former, passed away in the heated air discharged from the rooms. The difference in the 61 per cent. and the 78 per cent. is possibly accounted for by the fact that the radiators in the case of the Hospital for Sick Children were hotter than the hot air supplied in the other case, and hence the larger amount of radiation.

The problem which was set by my clients of comparing the *actual forced circulation system* with an *imaginary gravity system* to do the same work in the same building proved a difficult one, and too much reliance is not to be placed on the comparison.

A gravity system would have needed 4in. flow and return pipes and 250sq. ft. of radiating surface—that is 6 per cent. more than the forced circulation system required. The 588ft. run of 4in. pipe would have had about 616sq. ft. of surface compared with the 231sq. ft. of the other system. The velocity of the water in the case of the forced circulation might very well have been 3ft. per second instead of the actual 2ft. per second. In this case the pipes might have been reduced from 1½in. to 1¼in., and then the wasteful radiating surface would have been 192sq. ft. instead of the actual 231sq. ft.

The loss by radiation from the flow and return pipes between the heater and the dining room in the case of a gravity system was estimated at 69,250B.T.U. per hour, compared with the 38,450B.T.U. lost in the forced system. Hence the percentage loss calculated on the quantity of heat sent out from the heater would have been 56.1 per cent., or 14.6 per cent. more than in the case of the forced system. For the gravity system the heater would have had to supply 30,800B.T.U. per hour more heat, *i.e.*, 33 per cent. more, and therefore 33 per cent. more coal would have been necessary, while the probable efficiency of the gravity system would have been 37 per cent. compared with the 49.4 per cent. of the forced system.

TRIAL NO. II.

This was of the heater alone, with the coils incrusted as the result of four months' use (*i.e.*, the incrustation was about $\frac{1}{30}$in. thick on the coils).

The results were as follows:—

Duration of the trial	1.42 hours
Total quantity of water passed through heater	5750lb.
Mean temperature of inlet water	65.8 F.

Mean temperature of outlet water	135.5° F.
Mean pressure above atmospheric pressure of steam supplied to the heater ...	6.54lb. per sq. in.
Total quantity of steam passed through heater	414.4lb.
Mean temperature of condensed steam	211.7° F.
Total quantity of heat given to water	401,000B.T.U.
Total available heat of steam used	463,000B.T.U.
Rate of transmission *of heat per sq. ft.* of coil surface in heater, per hour	12,430B.T.U.
Ditto, *per sq. ft. per ° F. difference* of temperature between the steam and the water, per hour	102.8B.T.U.
Efficiency of the heater = total heat given to water ÷ total available heat of steam used =	86.5%

TRIAL NO. III.

This was also of the heater alone, but after the coils had been cleaned.

The results were as follows:—

Duration of the trial	1.08 hours
Total quantity of water passed through the heater	4080lb.
Mean temperature of inlet water	66.1° F.
Mean temperature of outlet water	168.1° F.
Mean pressure above atmospheric pressure of steam supplied to the heater ...	8.3lb. per sq. in.
Total quantity of steam passed through heater	418lb.
Mean temperature of condensed steam	189.5° F.
Total heat given to water ...	416,500B.T.U.
Total available heat of steam used	468,300B.T.U.
Rate of transmission of heat *per sq. ft.* of coil surface in heater, per hour	16,860B.T.U.
Ditto *per sq. ft. per ° F. difference* of temperature between the steam and water, per hour ...	161.9B.T.U.
Efficiency of the heater = total heat given to water ÷ total available heat of steam used =	89%

In conclusion it is useful to estimate the cost of warming by hot water, and of hot water supply:—

1lb. of coal should produce 8.5lb. of steam at or below a pressure of 25lb. per sq. in by gauge. Hence, as in *Trial I.*, 1lb. of steam *passed through the heater* raised 51lb. of water from 194.4deg. F. to 211.5deg. F. (equivalent to 0.73 gallon of water raised from 60° F. to 180° F.), about 13lb. of coal were used per hour. The cost of this, taking coal at 20s. per ton, is 1.39d. per hour. (1s. 5½d. per 1000 gallons raised from 60deg. to 180deg. F.). This is exclusive of the steam supplied to the circulating pump: including this steam the cost is 2.31d. per hour, but if the exhaust steam from the circulating pump had been passed through the heater, then the cost would have been only 1.42d. per hour.

In Trial II., 5750lb. of water were raised from 65.8 to 135.5deg. F. by 414lb. of steam. Hence about 34½lb. of coal were used per hour, costing 3.69d. This is equivalent to 1s. 3¾d. per 1000 gallons of water per hour raised from 60deg. to 180deg. F.

In Trial III. 4080lb. of water were raised from 66.1 to 168.1deg. F. by 418lb. of steam. Hence about 45½lb. of coal were used per hour, costing 4.87d. This is equivalent to 1s. 3½d. per 1000 gallons of water per hour raised from 60 to 180deg. F.

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* * *

RECENT PRACTICE IN GEAR-CUTTING.

THIS practice is one of the phenomenal features in the machine shops of the present day. One need not be a very old hand to realise the absolutely revolutionary character of this development. The writer's experience goes back to a period when gear cutting was regarded as too expensive a luxury to be indulged in for the ordinary work of engineers. Very few were used even on high-class machine tools, while none were ever put on fixed or travelling cranes, or on the ordinary run of machinery.

The beginnings of the better practice date from, though in a rather half-hearted fashion, the cutting of change-gears for lathes. But many firms still retained the rough cast teeth, on the ground that they were better. The real era of progress began with the application of the motor drive to overhead travelling-cranes. That story hardly need be repeated. It is sufficient to note that speed reductions from motor to hoisting and travelling motions involved trains of gears, spur and bevel, which were noisy, and wasteful of power, so that cut teeth became a necessity. Then the obvious advantages of the worm-gear reduction could not readily be secured simply because accurate teeth were difficult to obtain, and because the friction was excessive. These things hastened a better practice, and the design of many new machines. Then the general applications of electric driving to machine tools in general, the demands for gears for tramcars and motor vehicles of all kinds, and lastly the substitution of geared speeds and feeds for belt cones in lathes and machine tools in general, have been, and are at present, potent causes in the development of a better practice.

Since economy in production is an essential condition, the result has been more accurate gears at lower costs. This has involved the displacement of many of the old standard machines of universal type by machines of special design, and therein lies one of the most interesting features of present-day practice. The specialities of a firm determine the type of machine to be used. Seldom is a machine of universal character now set down in a shop, but instead we have those best adapted for one, or perhaps two classes of gears only.

Gear-cutting machines may be variously classified. First, by the class of wheel produced in them, as spurs, racks, bevels, spirals, worm-gears. Second, by the method of cutting; as by rotary milling cutters, which impart the shapes directly; by planing, using a form tooth, and by methods of generation. The last named are the latest, and furnish the most interesting examples of a problem which is worked out in a number of ways. Without doubt it embodies the general type of the future.

With regard to tooth shapes, a result of the growth of gear-cutting machines is the inevitable displacement of the cycloidal teeth by a single curve tooth, which for all practical purposes is the curve known as the involute. Cycloidal or double-curve teeth cannot be generated, they can only be planed, or produced by rotary cutters. Single curve teeth can be generated by any cutter which has for its basis the rack tooth. The Brown & Sharpe practice has fixed a standard which is generally accepted, and the Brown & Sharpe proportions of teeth are also more largely standardized than any other.

The relative results obtained by the use of rotary cutters, form planers, and generating machines may be briefly stated thus:—

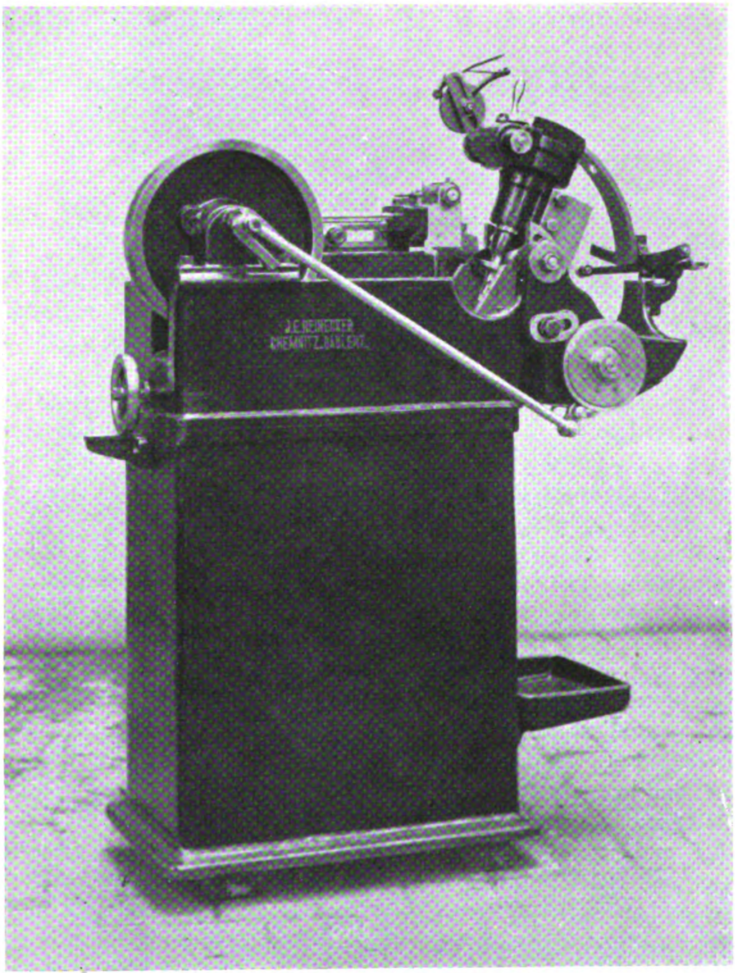

Fig. 1. Bilgram Bevel-gear Generating Machine. J. E. Reinecker.

The rotary cutters being made in sets can cut intermediate sizes only approximately correct. Though the variation from absolute accuracy is slight, the errors are there nevertheless. Form planer produced teeth depend for their accuracy on that of the forms, and though these are three times the size of the teeth the shapes of which they control, error may creep in. Yet in the case of bevel gears the form affords a far more accurate method than rotary cutters, which require two adjustments between cutter and blank to cut each tooth flank even only approximately correct. The generating machines possess the great advantage that whatever the design of cutter, it will produce accurate teeth in all wheels cut by it, instead of being accurate only by jumps or stages as is the case with rotary cutters. In some designs the principle or base is embodied in the cutter itself, as in the hobbing machines, in others in the mechanism of the machine, as in the Bilgram, the Robey-Smith and several others.

Although many examples of gear-cutting machines are built on one broad type, the individuals differ much in details. This fact is nowhere better illustrated than in the machines built for cutting spur gears only, familiar examples of which are those called to mind by the associations of the names of Brown & Sharpe, Gould & Eberhardt, in America, and Darling & Sellers, in England. But the machine of each manufacturer differs in detail in greater or less degree from that of others, and a study of these minor differences is one of much interest. These spur gear cutters are mostly made with horizontal work spindles, with the cutter spindle reciprocating beneath at right angles, its slide well supported on the stiff bed below. The machine of Darling & Sellers is an exception, having the arbor vertical, and the cutter slide moving perpendicularly on a head. In most machines the movements are all obtained from a single pulley, and all are automatic. A vertical member is provided to support the outer end of the work arbor. The dividing wheel is large, and situated at the rear of the head. All these features the machines have in common. Some variable features are the following:— The splitting of the rim of the dividing wheel, with hobbed teeth, in many machines. Friction-driven dividing mechanism by which shock is avoided when starting and stopping, and the use of elliptical gears for increasing and retarding the speed of the indexing motion. Multiple indexing adopted to avoid local heating. Thus, one or two teeth will be missed alternately in going round, and cut afterwards, so distributing the heating effects more equably round the rim than would be the case when successive teeth are cut. This is a matter worth considering in the heavy cutting now common. No extra change gears are necessary. The above features are embodied in the machine by J. Parkinson & Son, of Shipley.

Another variation is seen in the outer support for the work arbor of the machines by Ludwig Loewe & Co., Ltd. Here two uprights are adopted instead of the one which is usual. These are fitted at the front and rear of the bed, and the outer bearing for the arbor slides between them and is counterbalanced. Also, instead of being supported on a horizontal face as in the general design, they are fitted against vertical faces with tee grooves and bolts, and moved along with hand-wheel and screw. They are thus run along out of the way when they must clear the work.

Heavy machines of this type by various makers have provision for elevating and lowering the work spindle head by power through a screw. Most of them now have a waste oil tray running all around the bottom of the base casting.

The demands made for spur gears of

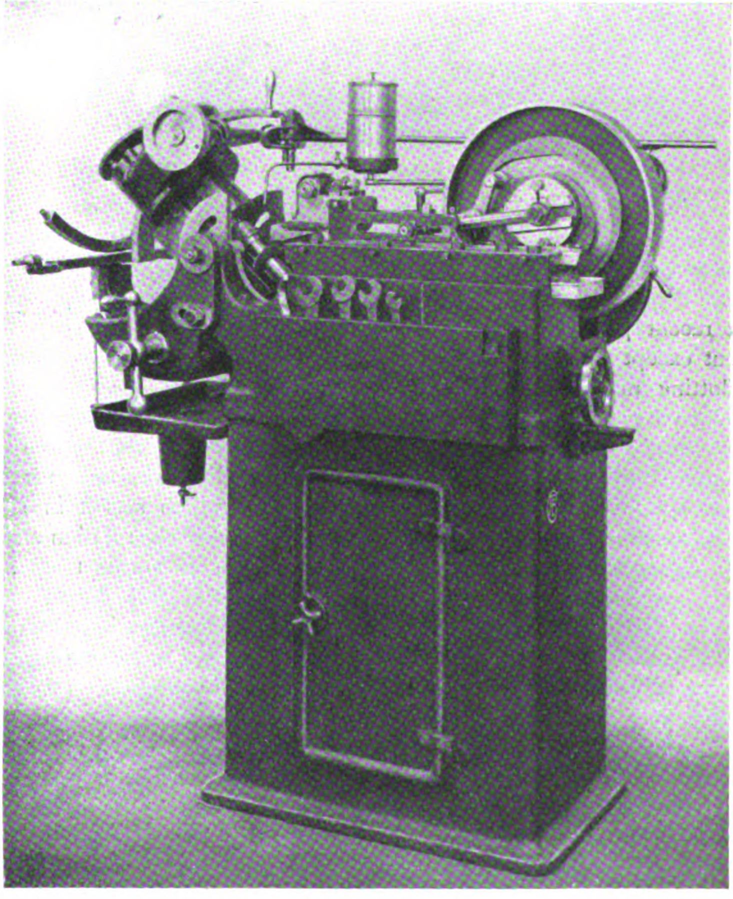

Fig 2. Bilgram Bevel-gear Generating Machine.

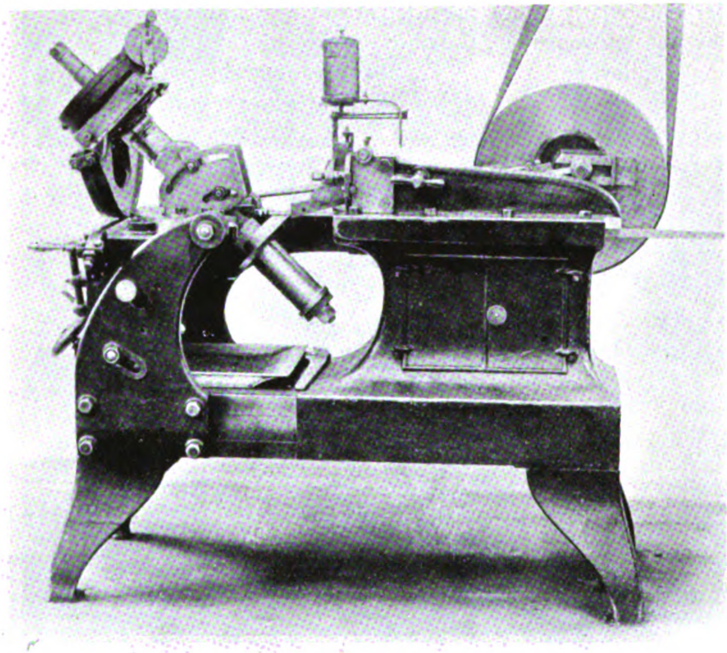

FIG. 3. BILGRAM BEVEL-GEAR GENERATING MACHINE.

ever-increasing weight has been instrumental in developing more massive designs, built after a different model from that of the more familiar spur gear cutters just noticed. Until a recent period large wheels could not be cut except by rigging up special rigs on a slotting machine in a makeshift manner. When large wheels have been wanted more accurately than they could be made from patterns, the wheel moulding machines have been resorted to. All that is now changed, and machines are made which will cut gears up to 20ft. in diameter by 36in. face, while those of lesser capacities are common.

In all these the type bears some resemblance to that of a plano-miller. A bed with flat ways and supported on standards carries the vertical work arbor with the indexing wheel below. The slides of the cutter spindle are movable on the face of an upright or housing sliding on the bed. The vertical feed of the cutter spindle slides gives the depth of face, and the movements of the housing give the depth of cut. Rotary cutters are used and the machines are either automatic, or indexing has to be done by hand. In these massive machines the weight of the spindle slides is counterbalanced. As in milling machines the outer bearing of the cutter spindle is adjustable endwise.

Much attention has been directed during the last two or three years to the machines which generate spur gears by means of a hob similar to that used for producing accurate worm wheels. The deal of hobbing spur gears is not new. It has been done in Reinecker machines for many years, but in a different type from that of the newer machines. The gear blank is mounted on a horizontal axis, the spindle rotating in a head on top of a stiff pillar. The hob is traversed underneath towards the head. The work spindle, driven by a dividing wheel, is connected to the cutter spindle by suitable change-gears to rotate the gear blank and the hob at the proper ratios. The hob is raised on its knee support to a height which sets it into depth of tooth at once, and the rotation and inward feeding proceeds until all the teeth are cut simultaneously to the full depth. In some respects this machine is built on the lines of the pillar and knee milling machine. The upright, the elevating knee carrying the cutter slides, an outboard support coming up from the base to support the end of the work arbor, and affording a bracing also to the outer end of the knee, follow milling machine design.

But all the new hobbing machines have their work arbors set vertically, besides which the essential mechanism is almost

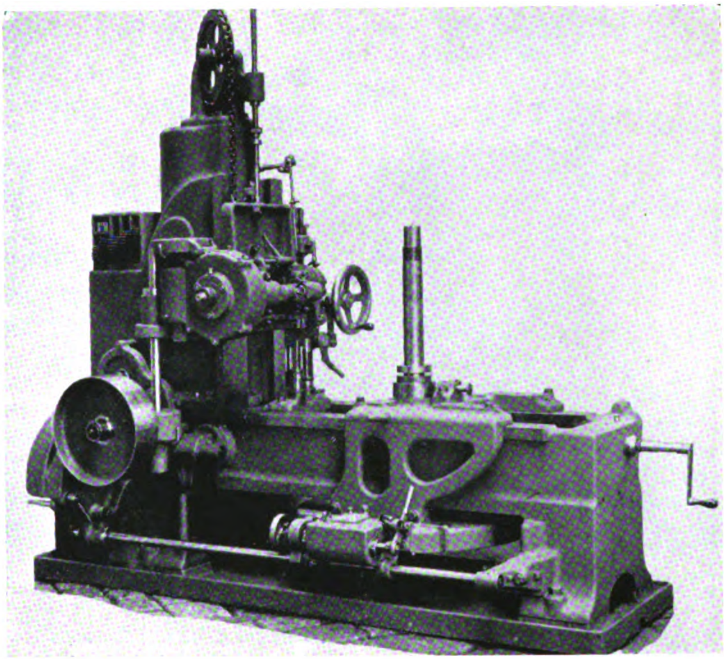

FIG. 4. SPUR GEAR-CUTTING MACHINE. DARLING & SELLERS, LTD., KEIGHLEY.

entirely different from that just noticed. Moreover they show many differences in design from each other. Some of them, like the Reinecker, are universal, being capable of cutting spirals as well as spurs, which involves a separate set of change-gears. Details are also worked out with more or less elaboration; and some machines are built of exceptional strength for heavy duty.

The hobbing machine has caught on as no other recent machine has, because the principle of generation is embodied, which is in harmony with modern requirements. There is the advantage also that ordinary rotary cutters can be used, but that is a concession to firms who possess a stock of these cutters. The important point is that a single hob generates all spur gears. whether large or small, of the same pitch with perfect accuracy. Compare this with the employment of the eight standard cutters which have to do service for the whole range of gears of a single pitch. In the ordinary set which is generally accepted, the No. 2 cutter has to serve for all wheels between 55 and 135 teeth, the No. 3 cutter for all between 35 and 54, the No. 4 between 26 and 34. A cutter can only be absolutely correct for a wheel of one size, so that all other wheels between the included numbers can be only cut approximately correct. The difference is not great, but approximations become increasingly objectionable to the modern machinist. So that an important advance is made when a single hob will cut all gears of the same pitch accurately. But the work is also done more rapidly, while a hob which has several threads will retain its accuracy for a longer period than a single cutter will do. Neither does any reversal with its consequent shock take place, but the cutter and gear-blank rotate continuously from the commencement to the termination of the work.

As the hob is a spiral or worm gear, and has to cut spur wheel teeth which are square or at right angles to the plane of the wheel, the hob is set at an angle with the plane of the gear being cut, that angle corresponding exactly with the angle of the spiral. This will vary with pitch and diameter. If the angle of thread happens to be 3deg., the axis of the hob is set by that amount out of the plane of the wheel to be cut. Moreover the method of cutting is different from that of worm wheel hobbing. The blank is set as stated in connection with the Reinecker machine, at correct centres at once, so that the hob begins to cut at its full depth. As

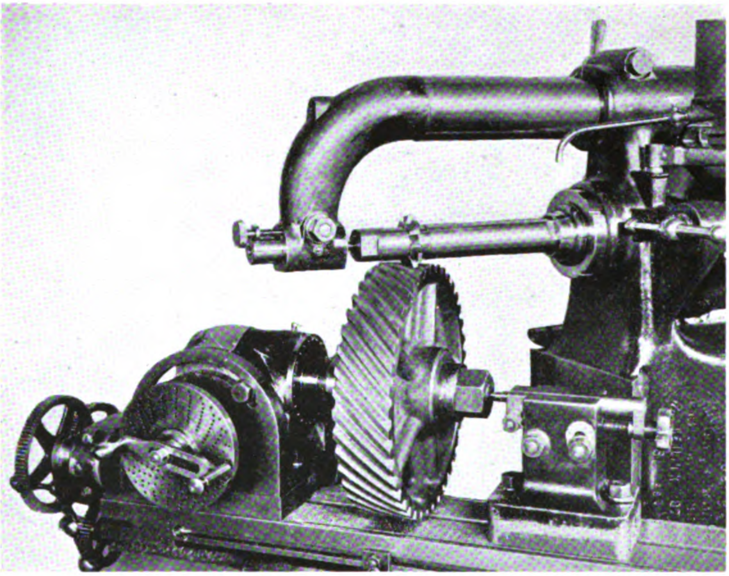

FIG. 5. CUTTING A SPIRAL GEAR IN A LUDWIG LOEWE UNIVERSAL MILLING MACHINE.

it is fed across the wheel face, the blank is revolved and the cutter is fed simultaneously with the regular revolution of the blank. The rate of revolution of the wheel blank synchronises with that of the hob cutter, otherwise interference must take place. This is provided for by two distinct sets of change gears, the pitching gears and the ratio gears, which are so set up that the cutter makes the same number of revolutions during one revolution of the blank as there are teeth on the latter. But the blank has to make some dozens of revolutions before the teeth are cut through. The number depends of course on the depth of face, and the fineness or coarseness of the pitch.

The details are worked out in the main as follows:—A horizontal bed, which is utilised as a tank to contain lubricant, carries an adjustable saddle or carriage in which the work arbor is stepped vertically. The dividing wheel and its worm are located and protected beneath the carriage. An upright at one end of the bed receives on its vertical face the carriage of the cutter slide, the weight of which is counterbalanced, and provision is made for feeding it downwards. The cutter spindle is driven at various speeds through spur gears, and is also made capable of swivelling to any angle, its base being indexed into degrees.

When hobbing worm gears, a hob of suitable lead and pitch being selected, its axis is set in the same plane as that of the gear blank, and not at an angle therewith as when cutting spurs. The gear blank instead of being set at correct centres in the first place, as in spur gear cutting, must be fed inwards towards the hob as the cutting proceeds. The axis of the hob remains in the same plane as the central plane of the gear, instead of being fed downwards. It is not necessary to use change gears for cutting worm wheels. If the teeth spaces are gashed first, the hob will feed the blank round as it cuts.

The case of spiral gears is rather peculiar. It differs from that of spur and worm gears as follow:—The axis of the cutter is set at an angle suitable for the particular gear to be cut. If a spiral gear is required to have teeth at 45deg. of angle the cutter is set at 45deg. plus its thread angle. The cutter has to be fed downwards into the blank, resembling so far the action of spur gear cutting. But it feeds at an angle, taking a helical direction in relation to the axis of the spiral wheel blank, and change gears have to be calculated to impart this differential motion.

A machine was patented some years ago for cutting racks with a hob. The driving and return mechanism is built on similar lines to that of a planing machine, namely, a rack drive with quick return operated by

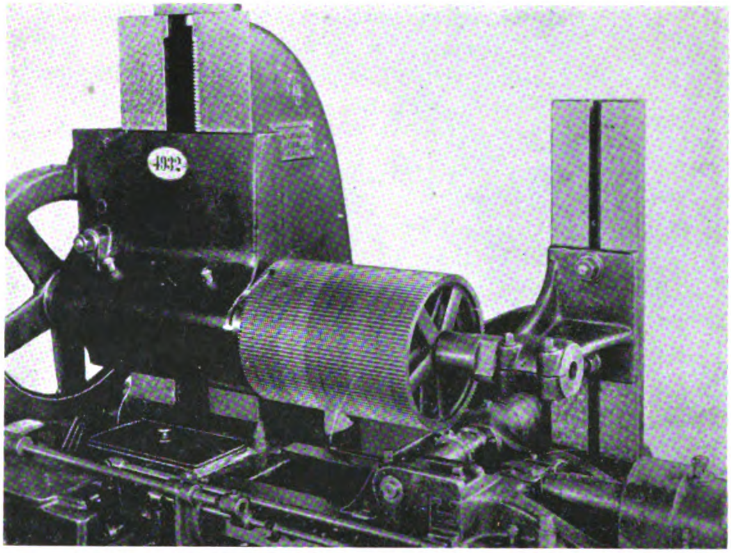

FIG. 6. CUTTING 12 SPUR GEARS SIMULTANEOUSLY ON LUDWIG LOEWE MACHINE.

tappets. The rack is carried on a cross slide fitting on the carriage, and the hob spindle is arranged over the rack blank at the bevel corresponding with its lead. A cut is taken along the length, and then reversal takes place when ratchets and screws feed the cross slide with the blank transversely under the hob for the succeeding longitudinal cut, and so on. The action as far as deepening the cut in succeeding cycles is concerned is identical with that of the spur gear hobber.

The utilities of such a machine are not very obvious, as the work of rack cutting is on a different footing from that of spur gears. A rack tooth has a constant angle, while the shapes of spur gear teeth vary with numbers of teeth. Moreover racks are already cut accurately and economically with rotary cutters. Economy is secured by laying similar racks in line, say from six to a dozen, and cutting through the lot; or by using multiple cutters which go through several adjacent teeth at once, and by a combination of both devices.

The generating process appears to be applied to rack-cutting only in one machine as a modification of the Fellows spur gear shaper. The same pinion-like cutter is used, and the mutual relations and relative motions are employed. That is, the cutter acts on the moulding principle in producing the rack teeth, only the moulding is done by cutting of the metal.

The form, former, or templet principle of cutting is a planing process in which the tool reciprocates like a planer or shaper tool, its movements being controlled by the edge of the form or templet. The designs of such machines are subject to much variation in the hands of different firms. Originally introduced for the planing of bevel gears, which cannot be cut perfectly accurately with rotary cutters, they have been made also in a few instances for planing spur gear teeth. The only advantage which the planing process has in this case is in the production of very heavy gears. The strains produced by the use of very large milling cutters are more severe than those due to a single pointed or single edged tool. The heavier the gears, therefore, the greater the reason why the method of planing should be selected. But few firms make them. The Gleason Company have them, and the Newton Machine Tool Works also, but built very differently. The Gleason machine has its spindle horizontal, and the cutting tool is mounted on a head traversing along a bed to one side, operated by open and crossed belts and a screw. A gear 20ft. in diameter can be cut, large gears being accommodated in a pit. The Newton machine is a modified slotter. The gear is mounted on a vertical arbor on a long bed, at one end of which the slotting column is supported. The table is indexed through worm gears and change gears by a separate electric motor. The templets against which the tool posts are pressed by springs are mounted in brackets on each side of the post.

The bevel gear-cutting machines which use a form or templet are represented chiefly by those of the Gleason Company, and the Oerlikon firm, and by those of Greenwood and Batley. These are not recent, each having been in use for a number of years. They differ much in details of design, having little in common beyond the fact that templets are used. The principle is extremely simple—namely, the strictly linear movements of the tool and the movements of the wheel blank are always in planes which meet at the apex of the pitch cone, controlled as to curves by the templet, and in regard to bevels by the mechanism of the machines. This involves two motions to the blank, one corresponding with that of the sectional bevel of the gear or that perpendicular to the axis, the other that in a lateral direction. In some the mechanism for carrying the wheel blank is pivoted at one side of the main frame, in others, and by far the larger number, it is carried on top of the main frame, obviously a more rigid construction. Most machines have but one shaper tool arm, but several have two arms cutting opposite sides of the same tooth, and reciprocating alternately. These machines are doing good work, and enable gears which for all practical purposes are absolutely correct to be manufactured at reasonable cost. The Bouhey machine planes single helical bevel gears.

At the present time the chief interest centres in the generating machines for bevel gears. The earliest type was the Bilgram, which is now made fully automatic, and which in spite of the rivalry of later machines is still a favourite. Its tool, of wedge shape, representing the rack-tooth section, is reciprocated by an arm moving rigidly between slides. The movements of the blank are controlled by one of the twenty-two roll cones, or evolvers in the series supplied, actuated through steel bands. All the flanks on one side are cut after preliminary gashing, and afterwards those on the other side. The movements of the blank have a peculiar appearance. They are compounded of an oscillation in a vertical plane, giving the bevel perpendicular to the axis, and of a rolling on the pitch surface, giving the lateral

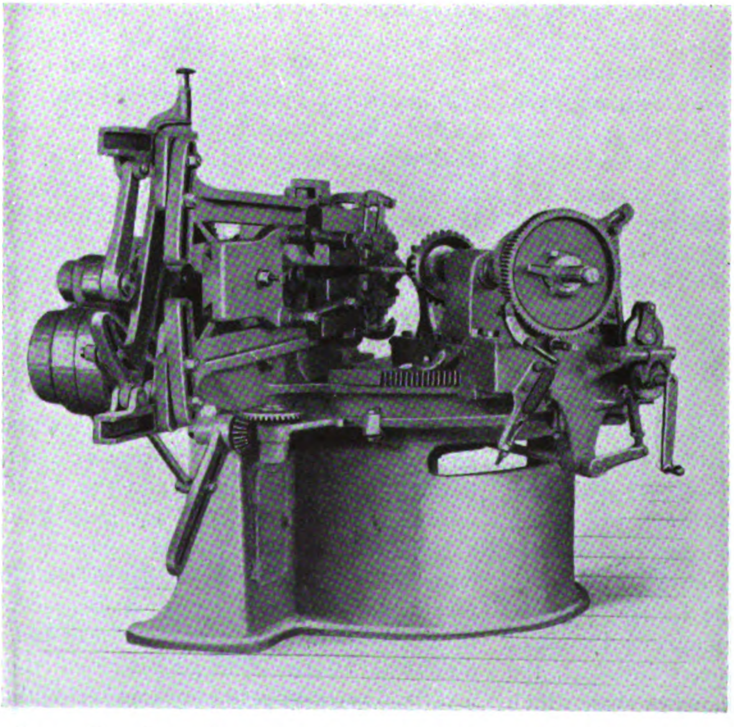

Fig. 7. Robey-Smith Bevel-gear Generating Machine by Smith & Coventry.

angles. As the blank is rolled against the reciprocating tool and rotated, the teeth are shaped in succession as the unwinding of one of the tapes pulls over the roll cone on its seating, the cone forming virtually the base circle of the involutes of the teeth. The roll cone has not been embodied in any other bevel-gear generating machine, though the Ducommon most nearly resembles it. The subject is now approached from a different point of view, namely that of a crown bevel-gear, that is, one the pitch plane of which does not form the surface of a cone, but is a horizontal plane. The teeth of such a wheel correspond with the rack teeth of the spur-gear basis of generation, and all bevel gears cut with it will be correctly shaped. The basis is simple enough, but the different ways in which the details are worked out are a most interesting study. The interest lies in the fact that the mechanisms of the machines themselves produce the required results, the movements of which cannot be explained in a few paragraphs. The principal machines of this class are the Robey-Smith, the Beale, the Warren, the Monneret, the Ernault, the Gleason, the Sunderland, and the Dubosc. In some the blank is rotated by a distance equal to the pitch between each cut. In one the teeth are of slightly helicoidal form produced by a rolling feed which is independent of the rotational movement. Machines cut either on one side only, or on both sides of a tooth

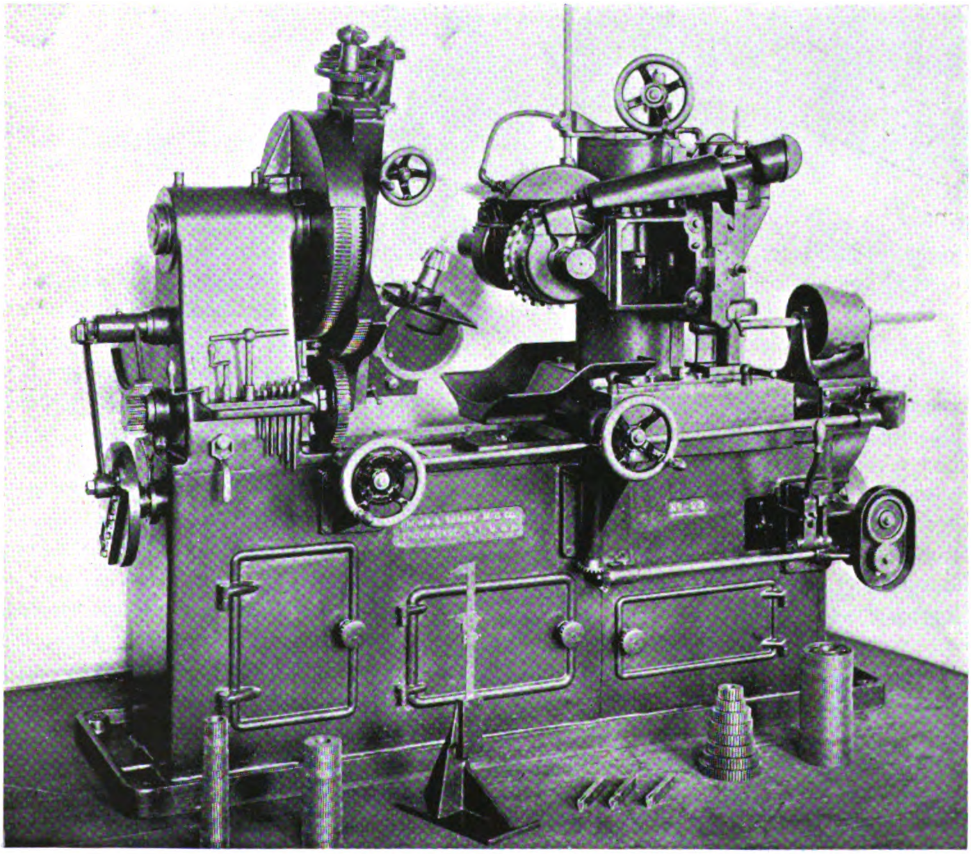

Fig. 8. Beale Bevel-gear Generator. Brown & Sharpe Manufacturing Company.

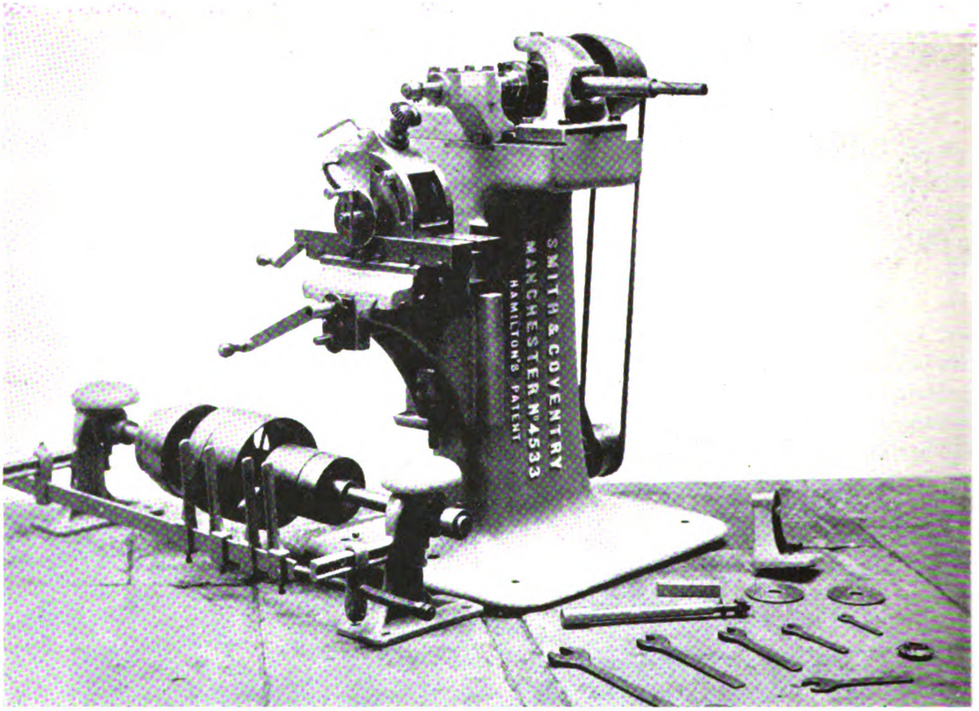

FIG. 9. HAMILTON BEVEL-GEAR CUTTER. SMITH & COVENTRY.

at once. Three of these machines employ rotary cutters instead of reciprocating tools. The Warren was the first to embody this device. The cutting faces of these rotary milling cutters correspond in angle with the angle of the crown gear teeth, and they are fed along the teeth of the blank with suitable slides which give the correct angle. The cutters operate on the inner or opposed faces of adjacent teeth in the Beale. Provisions are made for angular adjustments of slides to suit gears of different angles, and telescopic shafts and gimbal joints follow the movements.

The latest bevel wheel generating machine is the Sunderland patent, manufactured by the Churchill Machine Tool Company, Ltd., of Manchester. It first gashes round all the tooth spaces and afterwards finishes them. The cutter is in the form of a rack tooth, but its thickness is less than half that of the pitch at the small end of the teeth of the wheel to be cut, to permit it to clear. The gear blank is carried on a horizontal axis fitted with dividing gear and change wheels and supported in a slide movable in a horizontal plane round a quadrant on the base of the machine to impart the bevel to the teeth. It also carries a toothed segment operated from the tool slide to give the necessary roll to the work during the cutting of the teeth.

The cutting tool is carried in a quadrant head on the opposite end of the base facing the work head. The quadrant head carries tool slides which oscillate on it in a vertical plane. A crank disc imparts the reciprocating movement to the tool slide, being driven by a three-stepped cone. Connected to the bracket is a cam in which a runner is fitted operating a sliding plate connected to a toothed segment fitted to the tool slide. The object of this is to retard the speed of the tool slide on the quadrant, and cause slight rounding of the tooth points, to

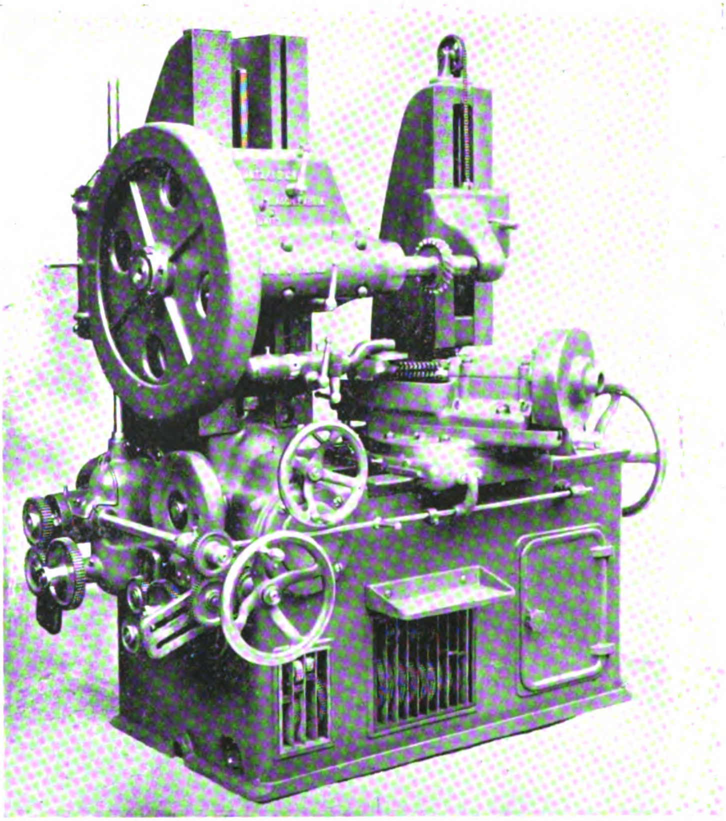

FIG. 10. AUTOMATIC GEAR-CUTTER FOR SPUR, WORM, AND SPIRAL GEARS.
BIERNATZKI & CO.

correct the interference due to the entry of the tooth points. The explanation of the working out of the precise details would be of little value in the absence of drawings. The crank disc at the side of the machine which operates the work head quadrant is provided with a vernier setting. A suitable index is provided to the quadrant. It is fed to the tool during gashing by a ratchet and pawl during a half revolution of the crank disc, when it is forced back quickly to clear the tool, and the dividing motion comes into action, following which the quadrant is moved slowly forward to allow the next space to be gashed, and so on automatically round the wheel.

Afterwards the teeth are completed by certain relative movements in which one side of all the teeth is finished, when by an alteration in relative positions the other side of all the teeth is finished.

Spur-gear generating machines were, until the advent of the hobbing machines, represented by one only—the Fellows. Here the principle is that one standard gear is capable of producing any other gear of any number of teeth of the same pitch to mesh with it. The action is as though the master gear were rotated at the proper ratio with the blank, and thus moulded the teeth of the latter. Actually the cutter is a gear, produced by a simple process of generation by a rotating grinding wheel, embodying the angle of a rack tooth. This gear, being hardened and backed off, is rotated with the blank at the ratios proper to the two, and being also reciprocated vertically, shapes the teeth in a blank of any diameter with a perfect generation of involute curves. The rest is a matter of detail. Feed arrangements cause the vertical or rotary movement to harmonise with the rotation of the blank. Change gears are used for pitching. The cutter is relieved from contact with the work during the return stroke. The cutter gives a draw cut, but it can be reversed if desirable, as in cutting down to a shoulder. Internal gears can be produced. A rack cutting attachment is fitted to some machines still using the same cutter, but substituting a linear movement in place of the circular movement for wheel blanks.

Another very recent automatic spur-gear generating machine has been brought out by J. E. Reinecker. It operates by planing, and the roll cones of the Bilgram machine are embodied. An advantage of this over cutters is that teeth can be produced with varying thicknesses, and of either normal or abnormal depths. Thus in cutting pinions with a small number of teeth, the teeth can be thickened, and the amount that is thickened can be deducted from the thickness of the wheel tooth.

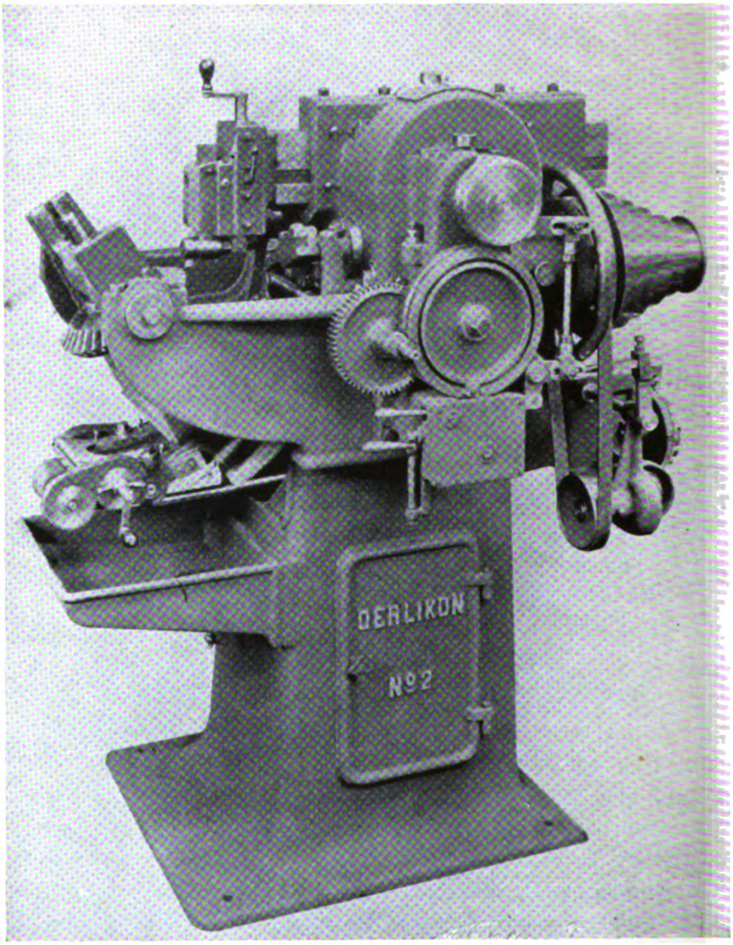

FIG. 11. OERLIKON BEVEL-GEAR PLANER. MASCHINENFABRIK OERLIKON, ZURICH.

The cutting of worm gears has passed through several stages. The practice of several years ago was to gash the teeth approximately with a fly cutter, correct for the tooth shapes of the middle plane of the wheel, and then correct the portions of the teeth between centre and ends where considerable differences in shape occur. This correction was done by chisel and file, using the worm as a templet, and in some cases by grinding in the worm with emery powder as a finishing operation. Then came the advent of hobbing. It grew slowly at first, because of the expense and difficulty of backing off and hardening. But with improved machinery and methods the hobs have become common. There is a method of hobbing worm gears used to a considerable extent, in which the hob is fed tangentially, to permit of which it is tapered longitudinally. This was due originally to Mr. Reinecker.

JOSEPH HORNER.

(*To be continued.*)

ELECTROLYTIC TINNING.

THERE is hardly any one process of doing anything that is "the best" for all conditions, so that the number of processes for securing any one result is constantly increasing, and at the same time new applications of the old processes are discovered. For protecting metals that are liable to rust or to be attacked by vegetable acids, &c., tinning is one of the most common and most efficient methods; but there is no one process of tinning that is available for all classes of articles which need such protective coating.

Up to within a comparatively short time ago, all metals with the exception of tin have been successfully—which means also easily and cheaply — deposited by electrolytic action; the general introduction of the dynamo having greatly facilitated this. But tin has proved itself somewhat resistant to attempts to deposit it thinly, evenly, and without crystals; and so finely that the coating will resist ordinary wear and use. This has been especially desirable in countries—such, for instance, as Germany—where cooking utensils, preserve and milk cans, and cocks and fixtures for beer receptacles, are required by law to be either tinned or enamelled. Where sheet iron, steel, or copper is tinned, it is, however, essential that it shall stand being bent, drawn, and pressed, without the coating separating or cracking, even where the latter is at the rate of 350 grains per square foot. The molten tin bath is naturally a source of loss by evaporation as well as by alloying with the metal of the kettle, and also should be used uninterruptedly to keep down the cost of fuel per article tinned. This method is, however, impracticable for large articles; and where they are hollow, but open at only one side, it is also difficult to secure an internal coating that shall be as regular and even in thickness as that on the outside.

A tinning process now quite successfully introduced in Germany for depositing very heavy coatings on articles of all sizes, is much the same as that used in ordinary galvano-plating, with the exception that the bath is kept at a temperature of between 50deg. and 60deg. C., or, say, 122deg. and 140deg. F. The bath is heated either by direct firing, by steam jets, or by a steam coil or double bottom, as desired; no pumps or stirring apparatus are necessary, and the regeneration of the liquid is effected by anodes. The time required is naturally dependent on the desired thickness of the tin coating. Small articles are preferably held in perforated baskets of sheet metal of convenient form, and about $\frac{1}{8}$in. thick. The bath is of enamelled cast iron, either with or without double bottom for steam heat.

The articles to be tinned are first to be cleaned from dirt, dust, scale, rust, soldering fluid, paint, &c. Those made of copper or of copper alloys are first cleaned with oxalic acid or its equivalent.

Iron and steel articles, if rusty or covered with scale, are pickled in dilute sulphuric acid and well scrubbed with a scratch-brush. Tumbling is recommended for such as will stand this process. If the articles are polished, turned, filed or stamped iron or steel, which are only dull from long standing, or only slightly greasy, it is sufficient to tumble them in a 5 per cent. soda solution for a considerable time. If they are very rusty or dirty it is well to wash them in 10 per cent. soda lye, then to pickle them in dilute sulphuric acid, then to rinse them in pure water, and finally to tumble them in weak lye and quartz sand. Fine sand makes them matt, coarse sand polishes them; the choice of sand must be made according to the articles. If a special polish is desired for iron or steel articles, they should be tumbled in a 3 per cent. soda lye to which some soft soap has been added. After the pickling or other cleaning processes the articles should be rinsed in running water to remove any remaining pickle or other liquid. The clean articles are then to be kept in clean water until the time comes to tin them; but this should be done as soon as possible.

Articles of lead or zinc can be tinned at once after casting, without any special preparation. If, however, they have been exposed to the air for a considerable time they must be scratch-brushed.

It is really advisable to tumble all articles which are to be tinned in the bath, in warm 10 per cent. soda lye.

The articles are placed in a perfectly clean metal pan which is attached to the pole of the battery or dynamo. This pan, after being used two or three times, must be pickled in dilute nitric acid and then thoroughly washed; and it is well to have two sets, used alternately, one being kept in the pickle while the other is in the bath.

The articles must not be piled on each other, as this would cause bare or thinly covered spots. Large ones should be turned from time to time. Those of very irregular form are best held in pans of specially adapted shape; sometimes it is well to have a metal cover-plate which shall lie on them and make better connection with the pole. Where articles are put twice in the bath it is well to rinse them between times in pure water. This water, once used, is added to the bath—naturally if it has been used to rinse tin solution from the articles it should not be added to a nickel or other non-tin bath.

The bottom of the bath gets gradually covered with sediment; and this should be removed from one to three times a week, in the morning, when the bath is cold. The clear bath liquid can be siphoned off by a clean rubber hose into a clean wooden tank, without disturbing the sediment; the bath tank is then to be scrubbed and rinsed with pure water.

R. GRIMSHAW.

THE VALUE OF GENERALISATION IN SCIENCE

By this term is not meant merely the value of "general" education to scientists. This value is undoubted, but represents quite a different phase of the subject to that dealt with here. The chief meaning of "generalisation," at least to the scientist, is that attached to such historical collections of data, and assertions therefrom of wide principles, as are those of Newton, of Maxwell, of Helmholtz, and of many others.

The world's greatest geniuses have been characterised by a remarkable power of generalisation — itself a sufficient proof of the importance of this process, for from an occupation which has exercised the most brilliant minds of all times, results of fundamental value must result.

Generalisation may be considered to be the deduction of broad laws and principles from a mass of data (obtained by calculation, deliberate experiment or casual experience). Successful and valuable generalisation is by no means a conclusion necessarily following on the collection of the data involved. In an experimental research, for instance, the individual conditions of each experiment are often given far too much importance by their observer. These conditions may continually vary, and the attempt to correlate them with the results obtained then leads to confusion and failure.

The great art of generalisation consists in sweeping away local details and petty points which appear at first sight to have vital bearing on the results, and laying bare the main underlying law to which all the experiments or cases of experience, apparently so widely distinct, are really subservient.

Generalisations deduced from one set of experiments or calculations have often been found to be applicable to a far wider field. Such have largely helped that interlinking of the sciences which is now recognised as so essential to progress.

The fact that man classifies various processes or phenomena as mathematics, sound, &c., cannot alter the fact that all things obey certain fundamental laws—"universal" in the true sense of the word.

Thus it may be said that generalisation consists in the representation in concentrated form easily applicable to any desired problem—the results of perhaps years of research.

Considering here the branches of science, each in themselves a science—mathematics, chemistry, physics (including heat, light, sound, and electricity) and general engineering—instances are to be found in each of the value of generalisation. The writer is not competent to comment on the generalisations of art, literature, history, medicine, &c., but is fully aware of their existence and importance.

The best idea of the value of generalisation is obtained by a study of the generalisations in each branch of science, noting the vast effect produced in each case. In every section it will be found that modern lines of thought and recent rapid development are all based on certain great generalisations on which depends the whole subsequent structure.

In some cases generalisations, at one time thought to be correct, have been found inaccurate in some respects, if not altogether. This does not in the least detract from the value of that generalisation up to the time of the discovery of error. It presented at the time of its inception a perspective of the data then available and so afforded a system on which subsequent work was based which led to further progress. That this progress proved the original generalisation faulty is no argument that the latter should never have been made. On the contrary it led to such researches as established *more nearly* the truth. The italics are necessary in the last sentence because it must be remembered that few of our generalisations are capable of *proof.* They are the summarised results of so much experience that *until a single exception is found* they may be accepted as facts.

Bearing this in mind, much of the panic and chaos which result whenever any doubt is thrown on a part or the whole of an empirical general law, may be avoided. In the past immense controversies have raged over certain alternative generalisations, *e.g.*, the corpuscular and wave motion theories of light transmission. Many exponents of the corpuscular theory (to deal with this example) seemed to consider that the whole science of optics, as then existing, must crumble to ruins if their theory, on which it had so far been based, were overthrown.

As a matter of fact, at the time this discussion arose, the effect on *past* results, of whether light transmission consisted of a corpuscular or vibratory motion, was absolutely nil, but the *future* development of the science was for the time being entirely dependent on the correction of the generalisation which so far had proved so fruitful.

Having thus indicated the general sphere of usefulness of generalisations, the main examples in each of the branches of science already mentioned may be considered.

In mathematics the generalisations of Newton laid the foundations for the whole subsequent development. His laws of gravitation and his general laws of motion have made our present-day efficiency in astronomy and mechanics possible. (Of course it must be remembered that in Newton's day science was so far advanced that had he not discovered his laws someone else must soon have done so. Progress inevitably leads to progress, and no sudden discontinuous advance is possible. Some special genius may accelerate the development by a few years, but as long as science is practised advances must assuredly occur.)

The calculus—both differential and its inverse, the integral—may be considered as another fundamental mathematical generalisation without which all modern calculations would be infinitely more tedious and many absolutely impossible. For years the principle of the calculus had been used to a more or less accurate degree, but rapid advances only occurred after these principles were collected and formed into a definite science with accurate laws of application to meet all possible conditions. By the formulation of such laws of usage new applications and processes can be found by analogy and extension, just as any number of "points" can be interpolated on a graph.

These, perhaps, are the most fundamental generalisations in the realm of pure mathematics, while in applied mathematics the increasing use of vector figures and stress diagrams, and the plotting of curves from experimental data, and deduction of equations to the curves (itself a process of generalisation), as well as our increasing knowledge of analysis of wave forms, have all led to great advances.

In the science of chemistry some of the most striking generalisations are to be found. This science is inherently one in which generalisations are possible, dealing as it does with the properties and interactions of and changes in materials. Apart from the great generalisations of physical chemistry, which have formed the basis of the science going by that name, and which include the laws of Marryat, Charles, Dalton, and Boyle, and the hypothesis of Avogadro, these finally culminating in the kinetic theory of gases, there are Dalton's atomic theory and

Mendeleef's periodic classification of the elements, standing out as mighty examples of the value of generalisation.

Perhaps the period classification of elements is the most potent example available of the points it is wished to emphasise. Though there are slight departures from the classification (which will probably eventually lead to considerable changes in our ideas), the value of the generalisation cannot be better evidenced than by *the discovery of several new elements* whose existence was only suspected from gaps in the classification. *The properties of these elements were very accurately prophesied* (again on the evidence of the classification) *before the search for the elements was even commenced*

During the past few years the generalisations regarding the molecular structure of materials have become so wide and precise that the manufacture of various steels, for instance, has resolved into an exact fulfilment of the given conditions of working—no longer has the work to be varied to suit the tool.

Electrically and electrolytically the subject of molecular structure is of vast importance.

The conservation of mass is a universal principle first realised in chemical research: it is a principle intimately bound up with the nature of heat, and the event of its formulation practically revolutionised chemical theory and practice.

Physics shares with chemistry the possibilities and fruits of vast generalisations. Treating the various sub-headings: *Heat*—The fundamental generalisation that has been established with regard to heat is that it is not a ponderable fluid, but, like light, is a wave motion (the wave length is, however, much shorter in the case of light).

As already indicated, from this principle, in the field of chemistry, followed the conservation of mass.

The second generalisation of importance, leading to the principle of the conservation of energy, is that regarding the mechanical equivalent of heat. The discovery of the possibility of converting work (mechanical or electrical) to heat and *vice versa*, and with a definite *exchange rate* (J. Joule's equivalent) makes all modern calculations regarding the efficiency of machines, &c., possible.

Light.—In the science of light the generalisation known as the wave theory of light has already been mentioned. For some time both theories regarding the nature of light transmission had their exponents, and both appeared to equally well explain known phenomena. At last, however, concurrent running became impossible, and the *crucial experiment*, mentioned in all text books, finally proved the correctness of the wave theory. (Or rather we should say the nearer approximation to the truth afforded by this theory; for when, some day, phenomena are observed incapable of explanation by our present theory, the latter will have to be again revised.)

Maxwell's electromagnetic theory of light was another stupendous generalisation, and forms a remarkable instance of the prediction possible by extending a collection of known results. Many entirely new phenomena were mathematically predicted in this case, including that which was, fundamentally, the basis of wireless telegraphy.

It is common knowledge how Herz, with his transmitting and resonator circuits, first transmitted and detected electric oscillations through the ether, and with this one step discovered the waves now bearing his name, laid the foundations of all wireless telegraphy, conclusively proved the correctness of Maxwell's theories (the whole of which follow in logical sequence once one part is *proved*), and finally overthrew all notions of "action at a distance."

Sound.—In sound no such striking and far-reaching generalisations can be instanced, but the development of the study of oscillations due to sound waves and the recording of the wave forms of various sounds has formed the starting point for an infinity of practical applications. Our knowledge of the nature of sound vibrations and the means of recording and reproducing them is well instanced by the telephone and gramophone.

Electricity.—In electricity one has such a complex science, composed of so many specialised branches of diverse application, yet all governed by a few simple laws, that the best instances of generalisation may be taken to be these all-pervading laws. First and foremost stands Ohm's law, that remarkably simple principle which, providing the conditions are as stated in its enunciation (viz., current and temperature both constant), is applicable to *every* electric circuit. Few laws have such a sphere of operation.

Kirchoff's laws are similar in their universal value and applicability.

To cite all the other available instances of generalisation in electricity would be to merely refer to the results of the researches of Faraday, Davy, and all the followers in that illustrious train.

Clearer ideas of the nature of electricity have been continually obtained ever since the first erroneous conceptions of electric fluids possessed of mass were abandoned.

The electronic theory, among others consequent on electrical research, has proved of immense value, not only among the associations connected with its inception, but also in the general field of physics and chemistry.

In general engineering, again, the same difficulties are experienced as in the case of electricity when endeavouring to collect the generalisations characteristic of that particular branch of science.

Engineering is fundamentally a science whose existence and progress depends essentially on the collection of results—on the formulation of general principles relating to every detail. The progress of the science as a whole depends on the progress and development of every detail, with the result that no all-including generalisations are to be found; but, no matter what subsection be referred to, there generalisations can be found which are the more comprehensive and complete the smaller the detail whose use and design is concerned.

This being so, only such broad principles as the increasing use of vector diagrams, the microscopic examination of materials, the tendencies towards compactness, cheapness, reliability, lightness and speed, and so on, can be referred to.

The value of these is known to every engineer—the design of complicated engineering structures by mathematics alone would be inconceivably laborious—the graphical solution is a relatively simple matter (especially if the peculiarly simple and valuable notation invented by Henrici be used).

The knowledge gained by our extended chemical, microscopic, and mechanical researches into the properties of pure metals, and even more especially of alloys, has led to most remarkable advances in efficiency, safety, and speed of operation.

Similar instances, each apparently of fundamental importance till it is observed that the next is equally valuable, could be multiplied indefinitely.

Taking science as a whole the most apparent and certainly the most valuable generalisation during recent years has been the increasingly universal recognition of *the value of generalisation.* Tests are systematically taken now in every possible instance: the data are obtained with extraordinary accuracy and are logically recorded. In this way a mass of information is collected which, viewed in every light, presents new knowledge and leads to a most rapid widening of our appreciation of the phenomena of Nature.

R. E. NEALE.

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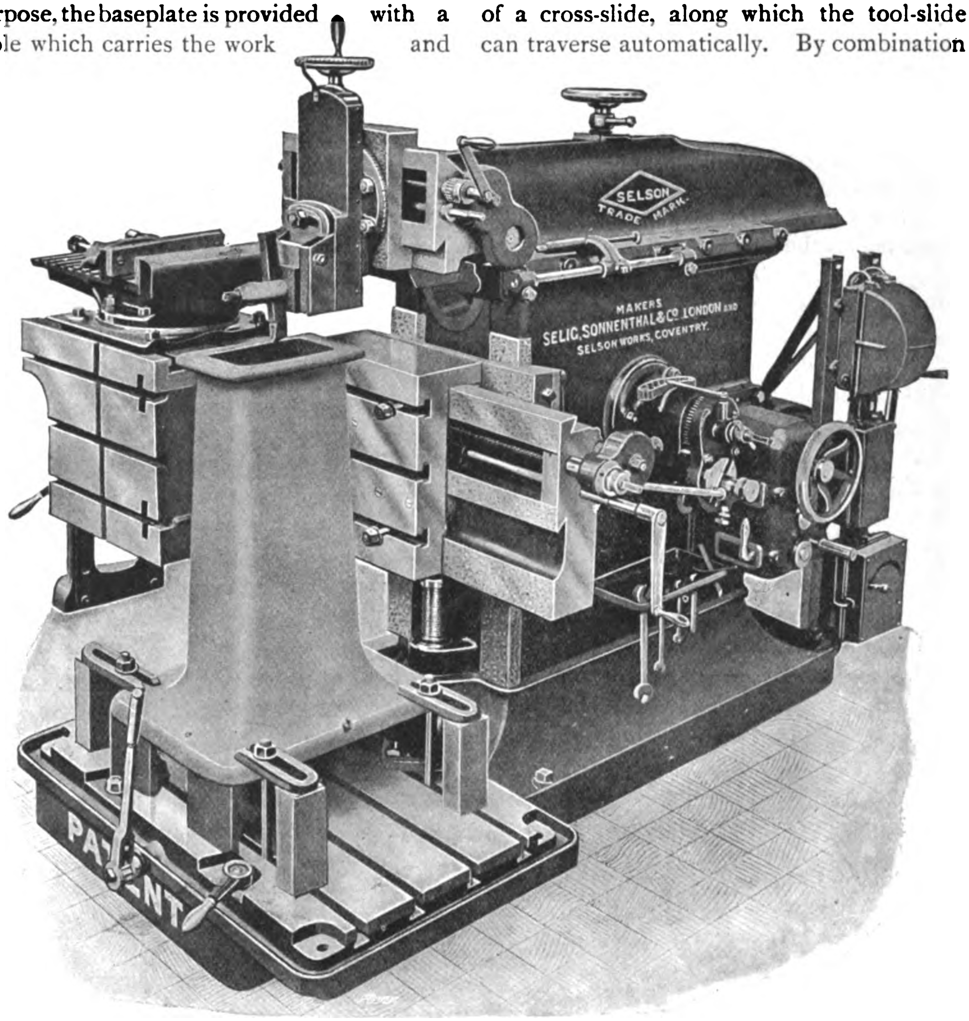
SHAPING MACHINE WITH TRAVERSING TOOL AND ADJUSTABLE BOTTOM TABLE.

THESE machines, which are made in two sizes, viz., 20in. and 24in. stroke, have been specially designed for operating on articles too large to be mounted on the ordinary rising and falling table, and, for this purpose, the baseplate is provided with a table which carries the work and can be traversed laterally, either by hand for adjusting purposes—which is the standard form of construction—or, if so desired, automatically.

The head of the ram is built in the form of a cross-slide, along which the tool-slide can traverse automatically. By combination



SHAPING MACHINE BY SELIG, SONNENTHAL & CO.

of the lateral movements of the bottom table and tool-slide, work usually done on the planer, such as machining the main bearings of small engine beds, &c., can be performed on this machine. To do this, the work is bolted to the bottom table, and the first bearing machined with the travelling tool. The table is then adjusted until the second bearing is brought to the position originally occupied by the first and the machining process repeated.

The ordinary rising and falling table is hinged to the cross-slide in order that it may be clear of the large work without the inconvenience of removal.

The machines are very heavy and the metal is judiciously proportioned to take all strains. The adjustment of ram is effected by a hand wheel placed in the most convenient position, viz., on the same centre as the handle for clamping the link to the ram. In other makes the adjustment is made from a separate centre. The index for the stroke is of an entirely new design, placed on the swinging feed bracket quite close to the adjusting handle and consequently in a much more favourable position than on other types of shaper, where the index is placed on the ram. The feed motion is of original design, by which the feed may be stopped, and then altered or reversed when the machine is running at full speed. The feed is also arranged to slip if the slide should reach the end of its stroke before the feed is disengaged, thus preventing a breakage of the feed mechanism. The handle for the back gear is brought to the front and is clear of the belt. On most other makes it is either placed right at the back of the machine or between the belt, the latter position being exceedingly dangerous and limiting the angle of the belt. The table support has a wide base giving better support to the cut on overhanging pieces. Roller bearings minimise the friction and are provided with felt wipers to protect the bearing surfaces from dirt or cuttings. The support is also placed further out than is usual on this class of shaper. The ram is of arched form, giving maximum strength where most needed. The top surface is serrated in order to give a better grip to the bracket connected to the rocker arm. The swivelling tool head is firmly locked to the ram by bolts, four of which are used in the 24in. machine.

Selig, Sonnenthal & Co. also make a full line of standard shaping machines from 8½in. to 24in. stroke, radial and other drilling machines, lathes, &c., &c., at their new works in Coventry.

THE DESIGN OF MOTOR STARTING RESISTANCES.

The advantages of the electric motor for driving machinery are now widely recognised, and the number of works electrically driven is rapidly increasing. An essential part of the equipment is the starting resistance, and although this piece of apparatus is of such importance it is only within the last few years that attention has been paid to its design, which previously was by rule-of-thumb, without any regard to the conditions under which it had to work.

The starter is subject to various working conditions, and in the hands of ordinary workmen with little or no knowledge of electricity, unless it be properly designed, may easily cause serious trouble.

Most of the starters now manufactured are fitted with the usual protective devices, viz., overload release and no-volt release, except in very large sizes, when the overload release is omitted and a separate circuit-breaker is used. A new type of starter has been patented in which the overload and no-volt release have been combined in one coil, which considerably simplifies the connections, makes the protection afforded by these more certain, and also lowers the cost of manufacture. As their name indicates these devices protect against overload and failure of supply, and also against any interference with the apparatus by unauthorised persons.

Whilst these devices are necessary more attention must be paid to the material used and design of the resistance coils.

The following notes may be taken as an indication of the lines upon which successful design depends. Most of the remarks upon the materials used and the coiling of wires are also applicable to all resistances, no matter for what purpose they are to be used.

The metals and alloys most commonly used for resistance wires are galvanised iron, German silver, platinoid, and manganin, and some other alloys for which the makers claim some special advantage.

The cost of these materials differs per lb. of wire of the same gauge, but the specific resistance also varies in about the same ratio, so that the higher the price the greater the resistance for a given quantity of the same gauge of wire. The result of this is that to obtain a given resistance the cost of the wire works out about the same for all materials.

A material of low specific resistance, if used to obtain a fixed resistance, will require a longer length of wire than a material of high specific resistance. Long lengths of wire increase the cost of frame and coiling; also it is usually desirable that the starter should occupy a minimum of space.

Some materials, such as German silver, become crystallised and brittle, due to repeated heating, and eventually the coils give trouble by breaking off, whilst others, such as iron, become soft, causing the coil to collapse and thus short-circuit itself.

Considering these points, it follows that any material, provided the price is not prohibitive, which (*a*) has a high specific resistance, and (*b*) is capable of withstanding the strains set up by alternate heating and cooling, will make the cheapest and most satisfactory job. In passing, it may be mentioned that although horizontal coils are best for dissipating heat, most manufacturers use vertical coils on account of the lessened liability of the coils making accidental contact with each other.

Let us now consider the gauges of wire most suitable for resistance coils. Usually nothing smaller than .022in. 24S.W.G. is used, because coils wound with such fine wires are mechanically weak, often breaking off at the joints. Coils are also affected by vibration, which often causes short circuits between adjacent coils. For heavy currents wires larger than .160in. 8S.W.G. are very difficult to coil, so that when a starter is to be used for heavy currents two or more coils are connected in parallel.

With regard to the gauge of wire to be used for a given current, this varies with different makers. The wire must, of course, be of sufficient area that it will be able to carry the current for the length of time it will be in the circuit without undue overheating. Practice varies in this respect, the rise in temperature allowed ranging from a few degrees above the temperature of the surrounding air to a temperature quite sufficient to discolour paper. No rule can be given for the size of wire or current density, as a great deal depends on the degree to which the convolutions of the spirals are separated from one another. With a fair spacing, however, a current of about one-sixteenth of that required to melt the wire employed, according to the table of fusing currents determined by Mr. W. H. Preece, may be taken as reasonable.

The following table gives approximately the resistance in ohms per yard and the current-carrying capacity of wires of different materials.

S.W.G.	German Silver.		Manganin.		Platinoid.	
	Ohms per yd.	Current.	Ohms per yd.	Current.	Ohms per yd.	Current.
8	.0159	20.2	.0298	18.6	.0288	18.6
9	.0196	15.9	.0368	15.1	.0355	15.1
10	.0248	14.9	.0467	13.7	.0450	13.7
11	.0303	13.3	.0568	12.4	.0547	12.4
12	.0377	11.7	.0707	10.6	.0682	10.6
13	.0481	9.0	.0903	8.2	.0870	8.2
14	.0637	7.4	.1196	6.4	.1154	6.4
15	.0786	5.8	.1475	5.5	.1421	5.5
16	.0995	5.3	.1862	4.8	.1803	4.8
17	.1300	4.2	.2439	3.7	.2349	3.7
18	.1769	3.4	.3320	3.0	.3206	3.0
19	.2548	2.6	.4782	2.3	.4616	2.3
20	.3146	2.2	.5905	2.0	.5699	2.0
21	.3982	1.7	.7475	1.6	.7213	1.6
22	.5201	1.5	.9762	1.3	.9422	1.3
23	.7079	1.2	1.328	1.1	1.282	1.1
24	.8435	1.0	1.581	.9	1.526	.9

In choosing the correct gauge of wire to be used for a given resistance, the current values given above may be doubled for a starting resistance, as these are only subjected to heating for short intervals.

Platinoid and manganin require nearly double these values to raise them to blood heat when exposed to the atmosphere and held horizontally. We can now easily determine what gauge of wire to use for given values of resistance and current.

After the gauge of wire to be used has been determined, the question of coiling arises. Mechanical reasons of stability make it necessary that different gauges of wire must be coiled into spirals of different diameters, lengths, and pitches, and this is also true in regard to dissipation of heat. Fine wires wound into large diameter spirals will simply collapse if placed vertically, and will sag if laid horizontally. Large wires, of course, cannot be coiled satisfactorily into small spirals; so it becomes necessary to determine the point where rigidity, heat radiation, and energy dissipation per unit of spiral length have their maximum value at the same time. This has been determined by experiment, resulting in these spirals being standardised, so that when the requirements of resistance and current-carrying capacity are known, it is now only necessary to specify a certain length of some particular spiral.

The following figures give approximate particulars of these spirals, and are based on the pitch of the spiral being twice the diameter of the wire, except in the small sizes, where the pitch is slightly more.

S.W.G.	Internal diameter.	Approx. length.
8	1 inch.	27 inches.
9, 10, 11	$\frac{7}{8}$,,	22 ,,
12, 13, 14	$\frac{3}{4}$,,	18 ,,
15, 16	$\frac{5}{8}$,,	14 ,,
17, 18, 19	$\frac{1}{2}$,,	11 ,,
20—24	$\frac{3}{8}$,,	8 ,,

We now come to the consideration of the resistance. In the case of a shunt-wound motor, if the armature at rest be connected direct to the mains, on account of the armature resistance being so small, by the formula $C = \frac{E - e}{R}$, where E = voltage of supply, e = back e.m.f. of armature, $R = Ra + Re$, where Ra = armature resistance, and Re = external resistance, the current will be very large, probably burning out the armature.

The object of the motor starter is, therefore, to put resistance in series with the armature, which must be gradually cut out as the speed increases.

In starting a motor the field coils must first be connected directly across the mains. In a shunt motor with practically constant field, the torque is proportional to the armature current, and by connecting the field magnet coils directly across the mains, this ensures a strong field in the air gap, with the result that a comparatively small current is required to produce the necessary torque or turning moment. The armature is then connected across the mains in series with a resistance of such magnitude that the initial current shall not be excessive. If the motor be started under full load, the armature current must be at least equal to normal full-load current before the motor will start. The armature current is thus dependent only on the torque of the load, which may be expressed as $T = kC$, where T is the torque due to the load on the motor, and k is a constant depending on the field strength and armature winding. The real value of k is =

$$\frac{.118 \times \text{field strength} \times \text{number of armature conductors}}{10^8}.$$

The back e.m.f., e, is proportional to the speed, and is expressed as e =

$$\frac{\text{field strength} \times \text{number of armature conductors} \times \text{revolutions per second}}{10^8},$$

which simplified is $e = kn$, where n = revolutions of armature per second.

$$\text{Now } C = \frac{E - e}{R}; \text{ therefore } CR = E - e$$

$$\text{or } \frac{T}{k} R = E - kn$$

$$\text{Hence } n = E/k - \frac{TR}{k^2} \qquad (1)$$

that is to say, for a constant load producing a torque T, each value of R has a corresponding speed at which the motor will run, and the larger the value of R, the lower will be the speed.

Returning now to the starting of the motor under load, a starting resistance could be made, so that on the first step the current $C = E/(Ra + Re)$ is more than enough to just move the armature. The motor will then run up to some slow speed, determined by formula (1), the current gradually falling to its normal full-load value. The starter arm is now moved on to the next stop, suddenly cutting out a section of the resistance. The current rises to a value corresponding to the decreased resistance, but gradually decreases to its former value as the speed rises. This is repeated until the whole of the starting resistance has been cut out, and the motor runs at its full speed, as given by formula

$$n = E/k - \frac{TRa}{k^2}$$

The resistance of the starter and the number of steps depends on the supply voltage, armature resistance, and load. The current-carrying capacity depends on the inertia of the motor armature, and the frequency of starting.

Let us now consider the subdivision of the resistance.

The starting conditions may be classified as follows:—(1) No load; (2) light load; (3) steady full load with little or no inertia; (4) steady full load with great inertia.

A definite decision must be made in the maximum current allowable at the start.

At each step in the resistance the current rises to a maximum and then falls to a minimum value. In a properly designed starter these maxima and minima should be the same for every step. Let us decide that the current shall vary between 1.15 times, and twice the normal full-load current, as these are usually allowed in a full-load starter. The total resistance on switching in should give nearly twice the full-load current, and can thus be easily calculated, viz.,

$$Ra + Re = E/(2 \times \text{normal full-load current}).$$

How shall this resistance be divided?

Let the total resistance of the armature and the last step to be cut out be R_1, and the resistance alone r_1, the next resistance step r_2, and the total resistance on this step R_2, and so on.

We then have

$$R_1 = Ra + r_1 \,;\quad R_2 = Ra + r_1 + r_2 \,;$$

and so on until we reach the last step, when $Rn = Ra + r_1 + r_2 \ldots + r_n = Ra + Re$, and n is the number of steps.

Let $\beta = \dfrac{\text{maximum current}}{\text{minimum current}}$; this we have previously decided shall be $2.0/1.15 = 1.74$. Then $R_1/Ra = R_2/R_1 = \ldots Rn/Rn-1 = \beta$; therefore $\beta n = \dfrac{R_1}{Ra} \times \dfrac{R_2}{R_1} \times \ldots \dfrac{Rn}{Rn-1}$

$$= \frac{Rn}{Ra} = \frac{Ra + Re}{Ra}$$

$$n \log\beta = \log\left(\frac{Ra + Re}{Ra}\right)$$

$$n = \log\left(\frac{Ra + Re}{Ra}\right)\Big/\log\beta.$$

We thus obtain a value for n, and we should make the number of steps in our starter the next whole number larger than n.

Proceeding, the resistance commences with Ra, and increases in geometrical progression with the ratio β. The values of the resistance steps then are as follows:—

$$Ra\,;\ R_1 = 1.74\,Ra\,;\ R_2 = (1.74)^2 Ra\,;\ \ldots\ldots\ Rn = (1.74)^n Ra.$$

In a similar way, if we wish to design a starter which will never allow the momentary starting current to exceed the normal full-load current by any other fixed amount, say, 1.25 times or 1.5 times, we can proceed as follows:—

Number of steps, $n = \log\left(\dfrac{Ra + Re}{Ra}\right)\Big/\log\beta$,

where β is the ratio of the maximum to the normal current, that is 1.25 times or 1.5 times, or whatever value we may have decided on.

Total resistance which must be in circuit on starting $Ra + Re = E/\beta \times$ normal full-load current.

Proceeding as before, resistance again commences with Ra, and increases in geometrical progression with ratio β, and the steps are, therefore, Ra; $R_1 = \beta Ra$; $R_2 = (\beta)^2 Ra \ldots\ldots Rn = (\beta)^n Ra$.

Perhaps an example will better illustrate these methods. We will, therefore, consider the case of a motor whose normal full-load current is 20amp., at 400 volts, Ra being 0.25 ohms.

In the first case, the resistance is to allow from 1.15 times to twice the normal current.

$$\text{Total resistance } Ra + Re = \frac{E}{2C} = \frac{400}{40} = 10\omega.$$

$$\text{Number of steps, } n = \log\left(\frac{10}{0.25}\right)\Big/\log\beta$$

$= \log 40/\log 1.74 = 6.6$. The number of steps will therefore be 7, this being the next largest whole number larger than the value of n from formula.

The resistances will then be:—

$R_1 = 1.74 \times .25 = 0.435\omega.$
$R_2 = (1.74)^2 \times .25 = 0.757\omega.$
$R_3 = (1.74)^3 \times .25 = 1.317\omega.$
$R_4 = (1.74)^4 \times .25 = 2.291\omega.$
$R_5 = (1.74)^5 \times .25 = 3.986\omega.$
$R_6 = (1.74)^6 \times .25 = 6.936\omega.$
$R_7 = (1.74)^7 \times .25 = 12.068\omega.$

$\therefore$ $Ra + Re = 12.068\omega$, and resistance of the starter must be $12.068 - 0.25 = 11.818\omega$.

The current on starting will be $\frac{400}{12.068} =$ 33.1amp.

The total resistance of the starter must be sub-divided as follows:—

Between		Resistance.
1st and 2nd stud	12.068 − 6.936	= 5.132ω.
2nd ,, 3rd ,,	6.936 − 3.986	= 2.950ω.
3rd ,, 4th ,,	3.986 − 2.291	= 1.695ω.
4th ,, 5th ,,	2.291 − 1.317	= 0.974ω.
5th ,, 6th ,,	1.317 − 0.757	= 0.560ω.
6th ,, 7th ,,	0.757 − 0.435	= 0.322ω.
7th ,, 8th ,,	0.435 − 0.25	= 0.185ω.

In the second case we will assume that the starting current must not exceed 1.5 times the normal full-load current, $\beta = 1.5$. $\therefore$ maximum current = 1.5 × 20 = 30amp.

Resistance to give 30amp. at 400v. = $13\frac{1}{3}\omega$.

Number of steps $n = log\left(\frac{13.33}{0.25}\right) \Big/ log\, 1.5 = 9.8.$

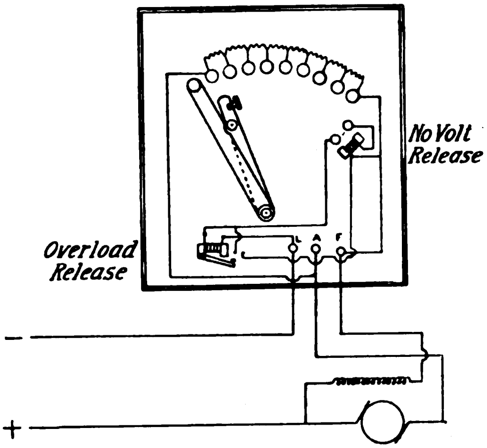


FIG. 1 DIAGRAM OF CONNECTIONS OF ORDINARY-TYPE STARTER

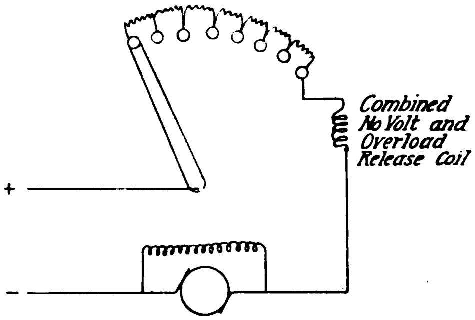


FIG. 2. DIAGRAM OF CONNECTIONS OF NEW-TYPE STARTER.

Next largest whole number = 10, and the resistances will be—

$R_1 = 1.5 \times .25 = .375\omega.$
$R_2 = (1.5)^2 \times .25 = .562\omega.$
$R_3 = (1.5)^3 \times .25 = .843\omega.$
$R_4 = (1.5)^4 \times .25 = 1.266\omega.$
$R_5 = (1.5)^5 \times .25 = 1.897\omega.$
$R_6 = (1.5)^6 \times .25 = 2.845\omega.$
$R_7 = (1.5)^7 \times .25 = 4.267\omega.$
$R_8 = (1.5)^8 \times .25 = 6.400\omega.$
$R_9 = (1.5)^9 \times .25 = 9.600\omega.$
$R_{10} = (1.5)^{10} \times .25 = 14.400\omega.$

$\therefore$ $Ra + Re = 14.4\omega$, and resistance of the starter must be $14.4 - 0.25 = 14.15\omega$.

The current on starting will be $\frac{400}{14.4} =$ 27.7amp.

The total resistance of the starter must be subdivided as follows:—

Between		Resistance.
1st and 2nd stud	14.4 − 9.6	= 4.8ω.
2nd ,, 3rd ,,	9.6 − 6.4	= 3.2ω.
3rd ,, 4th ,,	6.4 − 4.267	= 2.133ω.
4th ,, 5th ,,	4.267 − 2.845	= 1.422ω.
5th ,, 6th ,,	2.845 − 1.897	= 0.948ω.
6th ,, 7th ,,	1.897 − 1.266	= 0.631ω.
7th ,, 8th ,,	1.266 − 0.843	= 0.423ω.
8th ,, 9th ,,	0.843 − 0.562	= 0.281ω.
9th ,, 10th ,,	0.562 − 0.375	= 0.187ω.
10th ,, 11th ,,	0.375 − 0.25	= 0.125ω.

The starter in the first case is designed on the assumption that on switching in the current is not more than twice the normal full-load current.

As most motors are now started at any rate partly loaded, this design is the one most suitable for general use, the second case being for use where the motor may be started up light, and where, if the first design be used, it would cause a very sudden start.

Having now determined the resistance of each step, the next point is the size of resistance wire to use and the length necessary to give the required resistance, taking care to keep the temperature rise within the specified limits. This is obtained from table of resistances at the commencement of article.

The time of starting generally assumed in designing a starter is about half a minute; anything requiring a longer time has to have special attention paid to the size of resistance wire used, so that it will carry the current for the specified time without causing excessive overheating.

The resistance material of the larger steps can be overloaded more than that of the smaller ones. The overload allowed depends on the frequency of starting, the thermal capacity of the resistance, and the material — usually sand or asbestos — in direct contact with it.

With regard to starter arm, this should be provided with a laminated contact, in order to obtain more uniform pressure on the studs. The area of any stud should be of such dimensions that the current density does not exceed about 200amp. per square inch.

The "no-volt" release coil should be so proportioned that it will hold up the switch arm with the smallest field current taken by the motor, and adjusted to release when the motor speed has fallen to about quarter speed on the failure of the supply.

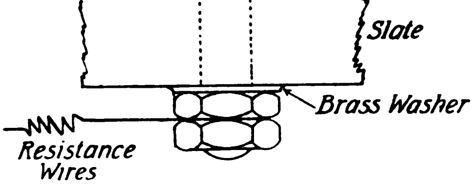


Fig. 3. Fastening of Studs and Resistance Wires.

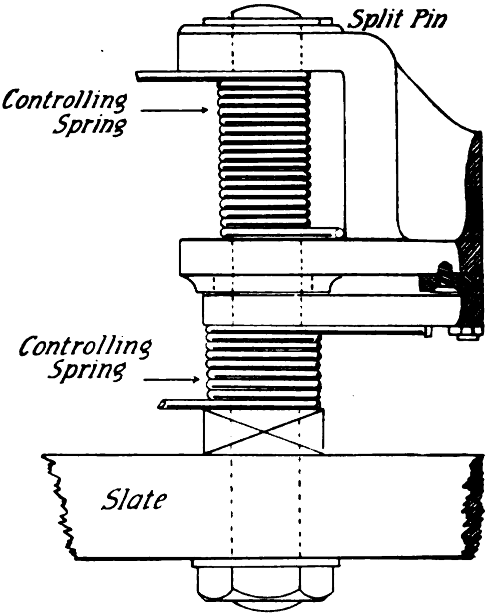


Fig. 4. Method of Fastening Starter Arm and Spindle.

Many electricity works and supply companies who use a large number of starters in connection with their motor hire systems are now doing their own repairs, and in many cases this is in the hands of one of the assistants who has little or no knowledge of the design of starting resistances, and who, when a burnt-out starter is brought in for repairs, patches it up with resistance wires, which he thinks will do for the job, and the starter is sent out again, probably to the same place as before, only to meet with the same fate. This has resulted in quite a large number of manufacturers not having any knowledge of electricity coming to regard electric driving as uncertain, and they have reverted to their former method of driving, which probably gave them some trouble, but which, by experience, they could themselves rectify. The author hopes that more attention will be paid to this work of repairing starters, and that these notes will be of service in this connection, as well as amongst the wider field of engineers by whom they are read.

Jos. W. Beswick.

ELECTRIC FIRE-ENGINES.

MOTOR-DRIVEN vehicles have found employment in practically every industry, in the service of individuals as well as authorities. As their chief factor is speed, it was natural that fire departments should take advantage of this type of vehicle. Yet it is a fact that the introduction of the motor-vehicle for this purpose has not made any very great headway, and by far the majority of fire stations, both in this country and abroad, are still equipped only with horse-drawn engines and escapes.

Probably the greatest drawback of self-driven cars is the uncertainty of their proper working. Naturally this is, for fire vehicles, a deciding factor; any appliance becomes useless if it cannot be depended upon with a full degree of certainty to reach the place of the fire as speedily as ever possible. Lately, motors for vehicles have been considerably improved, and it is now probable that their use for the above purpose will assume a wider extent. This is especially true with the electric motor cars which for city use are the most reliable medium of transportation. They are, indeed, more reliable than horses, and, of course, their capacity and speed are greater.

In numerous cities here and abroad electric fire vehicles are in use, but they are mostly experimental, and only at present supplement the horse teams. Greater Berlin, however, can boast of having a fire-station where no horses are employed at all, and only a few weeks ago another depôt was opened also entirely electrically operated. As this latter is probably the most up-to-date fire-fighting institution of its kind, a brief description will not prove uninteresting.

The fire-train consists of three cars, a chemical or gas-engine, a fire-escape or ladder, and the usual steam pumping engine. The first goes out first, and carries a full complement of the apparatus and tools required, and also twelve men. As a curious feature of this car it may be mentioned that the girders forming its frame are hollow tubes containing water for the first attack;

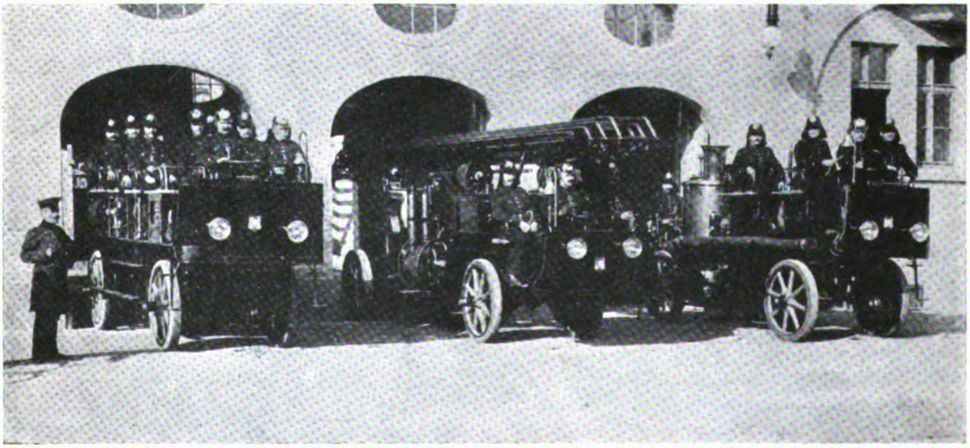


FIG. 1. NEW CHARLOTTENBURG FIRE STATION, SHOWING THE ELECTRIC MOTOR EQUIPMENT.

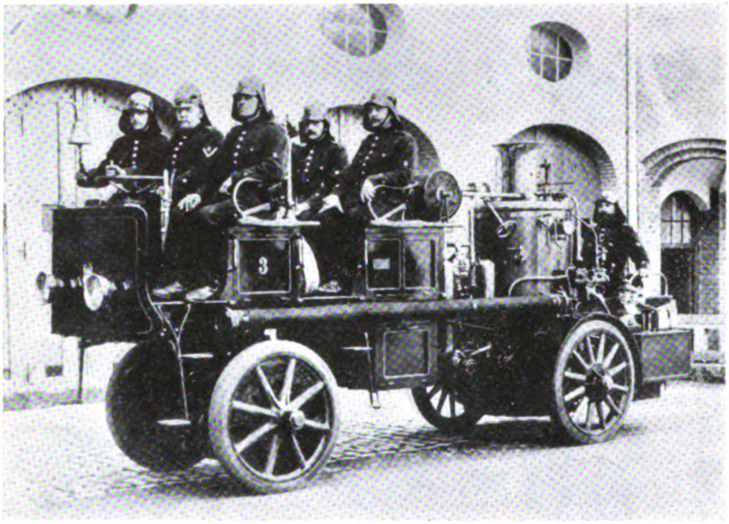


FIG. 2. THE ELECTRIC MOTOR STEAM FIRE-ENGINE.

this is driven out by chemical pressure. The fire-escape or ladder consists of telescopic sections, which can slide one within the other. The raising and extension of the ladder is done by an electromotor taking its current from the vehicle battery. The steam fire-engine differs from the ordinary types in that the boiler gives up its steam only for the pumping engine, and not for propelling the car. Thus the capacity of the former is increased. The boiler is fired with coke and coal during service, whilst when awaiting calls the water is kept constantly at 70deg. C. by gas-heating.

The propulsion of all the vehicles is done in the same way. On the chassis the batteries are mounted, having a capacity of about one hundred ampere-hours. They feed two electromotors mounted within the front wheel, assuring a most direct drive. There are five speeds forward, and two reverse. The charging of the batteries is done in the garage by taking the current from the municipal plant. This is an alternating current of 3000 volts, which has to be transformed in a special sub-station down to about 150-volt direct current. When the batteries are charged each car can run

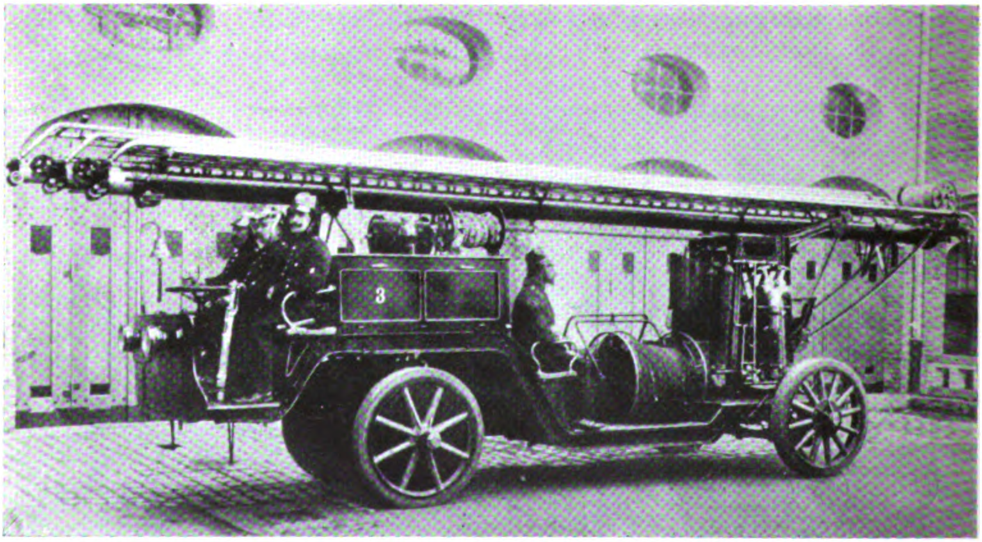


FIG. 3. THE ELECTRIC FIRE-ESCAPE. THE VEHICLE IS PROPELLED BY ELECTRIC POWER, AND THE LADDER IS ALSO EXTENDED BY ELECTRIC MOTOR.

continuously a distance of about twenty to twenty-five miles, which is far more than sufficient, as the average run from the station to the fire and return is about two to four miles. Thus a vehicle can go to several fires without re-charging. Provision is made so that charging can be interrupted at any moment, also that each car can be charged separately or all at one time. The wheels are fitted with solid rubber tyres, and during the time the vehicles are standing still, struts take up the weight from the tyres.

The arrangement of the whole station is entirely up-to-date. All rooms for the men and the vehicles are on the ground floor, to ensure immediate turning out to an alarm. Although the initial cost for the electric equipment was much higher than for the horse-drawn cars, calculations have shown that the running expenses of the electric-motor vehicles are lower.

MAX BRÜNNER.

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The Fixation of Nitrogen.

ACCORDING to a note in "L'Electricien" Dr. Schönherr of the Badische Anilin und Soda Fabrik has invented what promises to be an important improvement in the production of nitrates from the atmosphere by the electric process. As is well known the Birkeland-Eyde process consists essentially in blowing air over the surface of a high-tension alternating-current arc which is spread out to a sort of flat umbrella shape by the action of a powerful electro-magnet energized with continuous current. In passing over the arc the oxygen and the nitrogen of the air combine to form nitrogen oxide (NO_2). Dr. Schönherr's improvement consists in making one of the electrodes an iron rod, insulated from, but placed inside, an iron tube which forms the other electrode. The iron rod terminates at some considerable distance down the iron tube. At the point where the rod ends, air is blown tangentially into the tube, and is forced out of the open end of the tube. On starting the current a short arc is formed between the insulated rod and the nearest point in the tube. As soon as the air supply is admitted this arc is blown along until it stretches the whole distance from the rod to the mouth of the tube. A portion of the air blown through is converted into nitrogen oxide, and owing to the rapid cooling effected by the external air, none of the compound is lost by dissociation due to the heat of the arc.

The great advantage of this arrangement lies in the possibility of using ordinary iron for the electrodes, and the great regularity of its action; besides which it does away with the necessity for an electro-magnet and saves the power consumed thereby.

In a 1000h.p. installation the arc attained a length of 7 metres (27ft. 6in.), and the volume of air passing through the tube reached the high figure of 1100 cubic metres per hour. The escaping product contains from 1½ times to twice as much of the compound as is produced in the Birkeland-Eyde process, and in addition the whole arrangement is electrically more efficient.

Once the temperature of the compound has fallen below 600deg. C. it starts to take up more oxygen from the surrounding air, thus forming nitrogen peroxide, N_2O_5, which can be used in the ordinary way for making nitric acid or calcium nitrate. A factory is being erected in Norway to exploit this invention, and in two years' time the installation will comprise ten 14,000h.p. turbines. The formation of calcium nitrate for fertilizing purposes is accomplished by blowing the nitrogen peroxide over lime, with which it combines. The process follows the equation $CaO + N_2O_5 = Ca2(NO_3)$.

◆

COMPARISON BETWEEN THE VALUE OF SURPLUS GAS FROM REGENERATOR BYE-PRODUCT COKE-OVENS AND STEAM PRODUCED BY THE WASTE HEAT FROM BYE-PRODUCT COKE-OVENS.*

THE writer has often been asked which class of oven—the ordinary waste-heat type or the regenerator—should be put down; and in order to obtain Mr. Evence Coppée's views he enquired of that gentleman whether he could supply any data on the subject. The result is that he has furnished the writer with the following notes for publication.

The ironmaster who proposes to erect coke-ovens has to bear in mind two points: (1) the production of coke of the necessary quality and (2) its production in the requisite quantity to satisfy the demands of whatever number of blast furnaces he may have working. The production of coke is his first consideration, whilst that of bye-products, although by no means one to be lost sight of, is of relatively secondary importance in his eyes. The question, therefore, which he asks himself is this: How shall I best proceed in order to obtain the necessary tonnage and quality of coke at the least cost?

The colliery manager who has the erection of coke-ovens in view has small coal suitable for coking which he finds some difficulty in disposing of at a remunerative price. He therefore considers how he can best overcome this difficulty. His coal costs him *a* shillings, but if he transformed this coal into coke he might get $a + b$ shillings by taking the value of the bye-products into account (in this primary calculation he usually forgets the value of the motive power), and he reasons somewhat as follows. Instead of selling my *M* tons of coal, I will make coke out of it, and my profit will amount to *Mb* shillings. Having arrived at this point in his own mind his figure will be settled, and he will want to treat *M* tons of coal. Thus from the ironmaster's point of view as well as from that of the colliery manager the erection of coke-ovens is the result of either a tonnage of coke to be manufactured or a tonnage of coal to be treated.

The following questions are put by each to the oven constructor:—I have to treat *M* tons of coal per annum: what will the cost of coke-making be with that amount of coal? What process or what methods should I employ to reduce this cost to a minimum, in order that my installation should be kept down to the least amount possible? That is, I want the best result (low cost of manufacture and lowest cost of installation). These are the two points which must be closely connected in order to satisfy the business man of to-day.

The problem to be faced may therefore be generally stated thus: How to carbonize *M* tons of coal at the minimum cost. The solution varies with the varying circumstances which led up to the decision to carbonize these *M* tons of coal.

First of all, are the bye-products to be recovered or not? An elementary study will speedily settle this question. What is the value of the bye-products in the country under consideration? To determine this the term "bye-products" must be taken in its most general sense—that is tar, ammonia, benzol, and steam or gas. In Great Britain the question will practically always be decided in favour of recovery of bye-products; so that the form of ovens to be adopted will be "bye-product" ovens.

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* Abstract of paper read before the Institution of Mining Engineers, May 28, 1909.

But "bye-product" ovens are of two sorts—one which provides steam and the other which furnishes gas. Which then is it to be? Both sorts, namely, waste heat and regenerator ovens, are similar so far as their products are concerned—that is, as regards coke, the output, quality, labour, &c.; and as regards bye-products, tar, ammonia, benzol, &c., are also practically the same in both types. The first-named will furnish steam, the value of which per ton of coke produced may be called v; the second type will provide gas, the value of which per ton of coke produced may be called g. The cost of the manufacture of coke will differ in each of the two as regards upkeep of the ovens and amortization of the capital cost.

If the cost of coke-making in the ordinary waste-heat bye-product ovens be taken as Pf, and in the case of regenerator bye-product ovens as Pp, then $Pf = c$ (cost of coal per ton of coke) $+f$ (cost of manufacture) $+e$ (cost of upkeep) $+h$ (general expenses) $+a$ (amortization of capital) $-s$ (value of tar, ammonia, and benzol) $-v$ (value of steam); and $Pp = c + f + e + h + a' - s - g$ (value of gas). The surplus gas, as well as the waste-heat gas, are taken at the outlet of the oven plant.

The difference between these two costs can be stated thus:—$Pp - Pf = (a' - a) - (g - v)$. If $Pp - Pf$ works out as plus, regenerator ovens will be employed; but if $Pp - Pf$ works out as minus, waste-heat ovens will be used. The problem then resolves itself into a study of the following:—(1) The relative value of each system of ovens from the point of view of amortization and upkeep; and (2) the relative value of steam and gas. The writer will now consider these two questions under their respective headings, namely:—

(1) *Waste-heat and Regenerator Ovens.*—In order to judge of the relative value of each kind of oven as regards the working cost, the writer has stated that the labour of manufacturing coke and bye-products, the various initial expenses, and general expenses come to the same in both types. The following questions must then be considered:— (a) the cost of the installation (and its amortization); and (b) the upkeep.

As regards (a), it may be admitted without any great probability of mistake that regenerator ovens cost, for a given tonnage, about 25 per cent. more than waste-heat ovens—that is, counting only the ovens and chimney and exclusive of the boilers and, of course, the bye-product plant.

To put it again in the shape of a formula, if the cost of the waste-heat ovens alone $= P$, that of regenerator ovens will be $1.25\ P$. The cost of the bye-product plant being U, and that of the preparation of coal for the ovens G, the total cost will be $P + U + G$ and $1.25\ P + U + G$ respectively.

The problem may also be considered in order to see how the amortization will work out. For this purpose, the same formula, P and $1.25\ P$ respectively for the two types of ovens will be retained. With a little reflection it is evident that, in view of the increased amount of heat which is found in the regenerator ovens, and therefore more rapid wear and tear, a higher rate of amortization must be provided for than in the case of waste-heat ovens. If the latter be amortized in 12 years, the regenerator ovens should be amortized in 9 years. It will, therefore, counting interest at 4 per cent. work out according to redemption tables as follows:—For waste-heat ovens, $0.1065\ P$; for regenerator ovens, $0.1344 \times 1.25\ P$.

By dividing these sums by the annual coke tonnage, the cost of coke-making in each type of oven will be obtained from the point of view of amortization. The above represents annually a difference of (0.1344 × 1.25 – 0.1065) $P = 0.06\ P$, or 6 per cent. of the capital for the erection of waste-heat ovens.

As regards (*b*), it may be considered that the cost of upkeep, seeing that regenerators are amortized more quickly, is the same in both types of ovens.

(2) *The Relative Value of Steam and Gas.*—In dealing with this question it must be first of all stated that it is here that the special conditions under which a plant has to be erected chiefly come into consideration. Has the prospective client need of all the motive power which regenerator ovens are capable of producing? If he does not need it all himself, can he sell a portion of it? Or will he be satisfied with only a part of the available amount.

What, in short, is the horse-power or the kilowatt-hour worth to him, after the amount which he has at his disposal passes a certain limit? It may be taken for granted that as a general rule he will claim the maximum power, and so be enabled to diminish the number of boilers he has to feed.

Under these conditions it is not difficult to ascertain what the battery will furnish in both cases; and in order to arrive at these figures each of the following questions will have to be considered:—

(1) What is the steam worth which is produced by boilers fed by coal costing *a* shillings per ton, *a* being the average price in any one district paid for boiler coal.

(2) What power can be produced by a steam-generating station; what will be the cost per kilowatt-hour in the case of waste-heat ovens; and what will the power be worth per annum, calculated on the value of the ton of steam as in (1)?

(3) What is the value of the fuel in kilowatt cost?

(4) What power can be obtained from regenerator ovens in a gas-generating station, and what will be the cost of the kilowatt-hour?

With the necessary data for these different items, one is then able to calculate (*a*) the value per annum of V, the motive power produced by waste-heat ovens, and (*b*) the value per annum of V', the motive power produced by the gas from generator ovens.

The value of $V' - V$ divided by the tonnage of coke per annum will give the amount saved in the cost per ton of coke. In order to determine these various items one must first know: (1) the cost of erecting a steam-generating station, and (2) the cost of a gas-generating station, including in both all accessories, such as boilers in the former, and purifiers, gasholders, &c., in the latter; and in both cases the cost of working the plant. The upshot of the foregoing is that the cost of coke-making in regenerator ovens is encumbered, in comparison with waste-heat ovens, with an annual manufacture of $365 \times N$ tons of coke, or

$$\frac{0.06\ P - (V' - V)}{365 \times N}$$

If this amount is minus, the regenerator type of oven is to be commended.

By way of illustration, the writer takes the case of one of Mr. Coppée's plants at Ressaix, in Belgium, where both systems are working simultaneously and using the same coal.

The waste-heat ovens, thirty in number, in this case cost approximately £24,000, and the thirty regenerators 25 per cent. more. The amount of coke produced in each case amounts to 4.75 tons per diem per oven, or 52,000 tons per annum. From the waste-heat ovens 730b.h.p. is obtained from the steam, while from the gas of the regenerator ovens the b.h.p. amounts to 2000.

This 730b.h.p. is equivalent to 16 tons of coal per diem, which at, say, 5s. per ton, represents £4, and putting labour in connection therewith at £1, a value of £5 per diem is arrived at, or £1825 per annum.

The 2000b.h.p. therefore represents

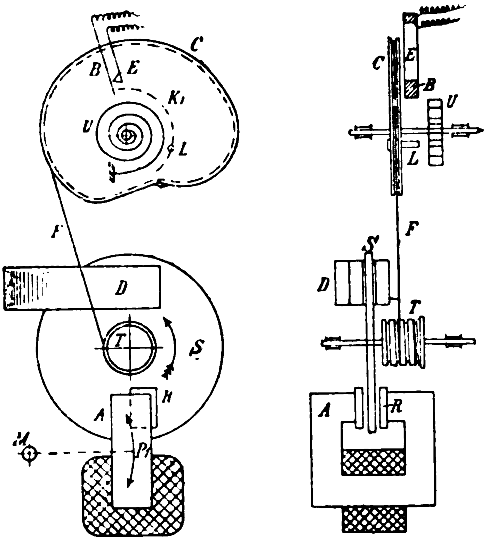
$\frac{1825 \times 2000}{730}$, or £5000 per annum. From the above figures *a* represents 8.42d. per ton of coke and a' 1s. 10d., whilst the cost of amortization of the ovens is 9.48d. for *a*, and 1s. 6.6d. for a' per ton of coke. Thus bearing in mind that the amortization of a plant is a negative quantity and the value of steam and gas a positive one, the net saving with gas per ton of coke amounts, according to the following formula, to $Pp - Pf = (a' - a) - (g - v) =$ (1s. 6.6d. − 9.48d.) − (1s. 10d. − 8.42d.) = 1s. 1.58d. − 9.12d. = 4.46d., the total value per ton of coke in favour of a gas-generating station.

The author may here state that the Belgian coking coal is as a rule considerably lower in volatile matter than English coal, and in the above case contains 19 per cent. of volatile matter. On the other hand, the coal charged into the ovens is considerably dryer, as the small fine duff is extracted before washing, and is mixed with the washed coal going to the ovens. MANSFELDT H. MILLS.

◆

Improved Time Limit Relay.

AN improved form of alternating-current relay is described in a recent number of "L'Electricien." This relay is of the wattmeter type with a differential arrangement of the timing disc. Both the time setting and the turning moment of the armature disc are adjustable by means of a key. The adjustment is made without opening the instrument, and can be done while the instrument is actually in use. In the accompanying figure *A* is an alternating-current electro-magnet with screen *R*. The magnet causes the disc *S* to rotate, and in so doing winds the cord *F* on the drum *T*, thus rotating the cam-shaped disc *C* against the action of a spring *V*. The shape of the disc *C* is designed so as to compensate for the increasing tension of the spring, thus securing uniform rotation. As the disc *C* is rotated, the pin *L* is brought round till it strikes the spring contact *B*, and so breaks or makes the contact *BE*, thus actuating the trip coils of the circuit-breaker. The pin *L* can be adjusted along the circumference of a circle *K* so as to make the time constant greater or less, and the effect of the main current can be enhanced or reduced by rotating the electro-magnet *A* about the centre *M*. *D* is a permanent brake magnet of the usual type. With an instrument of this type even a heavy short circuit will not cause instantaneous action. If, therefore, immediate action is desired, a special device is added, room being left for it in the case of the standard instrument. The magnet for this instantaneous circuit-breaker may be energized by the main current from a current transformer or from an independent source. In the latter case the current should not vary greatly even with heavy short circuits. These relays are wound for a current of 5amp.



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POWER TRANSMISSION BY CHAINS.

Chain drives possess many advantages which are at the present time but little understood by the majority of engineers. They are capable of wide application and comparatively recently much extension may have been noted. Much excellent work has been accomplished by Messrs. Hans Renold, Ltd, of Manchester, and the author is indebted to this firm for a considerable amount of information on the at present little known subject.

To briefly enumerate the advantages of chain driving it may be said that it is positive and its efficiency is very high and constant. No tension is required to make the chains grip their sprockets. There is an entire absence of slip, the minimum of journal friction, and a more economical use of power than with any other mechanical drive. Chain drives can be applied in cramped or awkward positions occupying little space. They give efficient service at centre distances too short for belts and too long for gearing, and are quite satisfactory in hot or damp positions. They are capable of wide application to many and varied classes of drive.

In the latter respect, however, it should be stated that several factors determine the best size and type of chain to be used, among which are: the nature of the drive, whether the load is steady or fluctuating; the speed required; and the power to be transmitted.

The before-mentioned firm are makers of three chief types of chains, illustrated at Figs. 1 and 2. Fig. 1 shows a Renold patent silent chain with hardened steel liners. The permissible speed of this chain is up to 1250ft. per minute, and even higher when special precautions are observed with respect to oiling or where extra durability is not a point of first importance. This type of chain can be made in sizes to transmit from ¼h.p. to 500h.p. Another type is the bush roller chain. Its speeds are from 400ft. to 900ft. per minute and the power capable of being transmitted on this type of chain is ¼h.p. to 200h.p. Fig. 2 shows the type known as the solid steel block chain. The

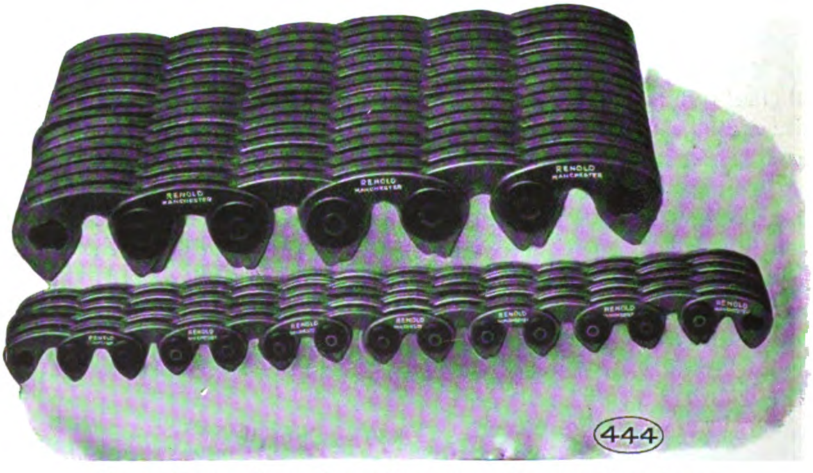


Fig. 1. Renold Patent Silent Chains with Hardened Steel Liners.

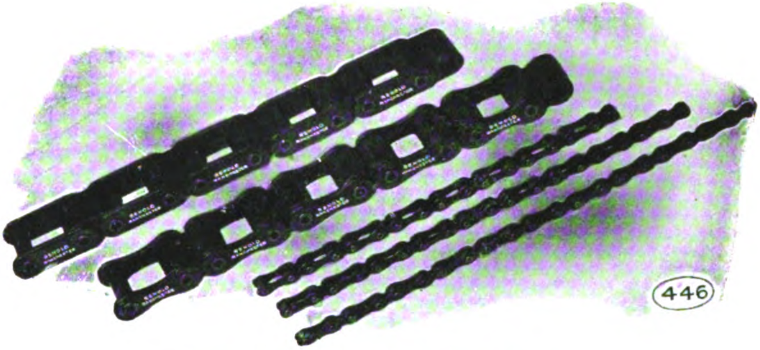


Fig. 2. Renold Solid Steel Block Chains.

permissible speed is from 200ft. to 500ft. per minute and power transmitted from ¼h.p. to 100h.p.

The Renold patent silent chain has now been thoroughly tested and has been proved to be extremely reliable. The illustration, Fig. 3, clearly illustrates the principle of the chain gearing. The chief characteristic of the silent chain gear is that the correct relation is maintained between the pitch of the chain and the virtual pitch of the sprocket teeth. As the chain wears it rises automatically on the sprocket to compensate for its lengthened pitch, as shown in Fig. 3. This automatic rising is due entirely to the special link and tooth form employed. Although this alteration takes place as the chain becomes worn, it will be noticed on inspection of the diagram that the links still engage as correctly with the teeth with which they are in contact as they do when the chain is new and unworn. By reason of this the load is distributed over all the links equally. Fig. 3 is a diagram showing the chain leaving or entering the wheel. It will be observed that when entering the wheel the links do not drop directly on to the teeth, but approach them at an acute angle. They come in contact, however, without sliding action. Another advantage is that each link, while in contact with its tooth, retains in general the position it first assumes.

Chains have a considerable working life, and generally it may be said that seldom is a driving chain not strong enough for the work it has to do, and it will usually wear out of pitch with the wheel teeth before it breaks. Naturally it is desirable that such a condition should be postponed as long as is possible, and therefore a size of chain should be selected which will ensure this. The life of a driving chain depends almost absolutely on the amount of pressure per

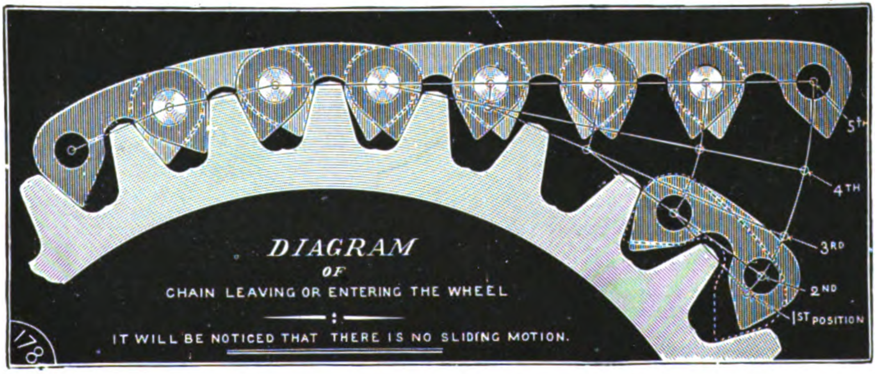


DIAGRAM
OF
CHAIN LEAVING OR ENTERING THE WHEEL
IT WILL BE NOTICED THAT THERE IS NO SLIDING MOTION.
5th
4TH
3RD
2ND
1ST POSITION
178

Fig. 3.

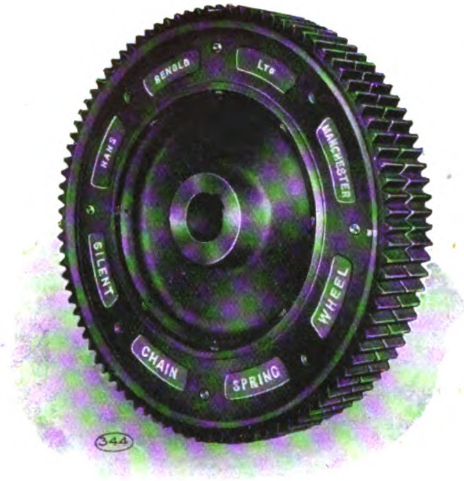


FIG. 4. COMPLETE SPRING SPROCKET.

square inch of wearing surface, *i.e.*, on the rivet bearings. Naturally it is of course influenced by the hardness and general quality of finish of such bearings. Both the wearing surface and the strength of a chain are governed by the rivet diameter, and therefore it is customary to select a chain by its strength, instead of calculating the rivet bearing surface. Messrs. Hans Renold state that to obtain a sufficiently durable chain the ratio between the pull and the breaking load should be, for :—

Silent chain	1 : 30
Roller chain	1 : 20
Block chain	1 : 15

As will be readily understood the factor varies to some extent with the speed; for instance, with the silent chain a factor of, say, 20 would be sufficient for good conditions, and a speed of only 500ft. per minute, and for carrier work in the block chain the factor is often only 5. An important consideration is that a chain well above its work is more economical than one below it; therefore it is advisable to use a larger factor in severe cases where the load is irregular or impulsive.

In Figs. 4, 5, and 6 views of spring cushion sprockets are shown. For an irregular drive this type of sprocket is strongly recommended. It will be observed that the springs are interposed between the rim and the boss of the wheel. Any fluctuations of the load are thus absorbed, and injury to the chain is obviated.

It is not desirable to employ higher ratios between driven and driver sprockets than the following :—

Silent chain	1 : 6
Roller and block types	1 : 7½

The maximum and minimum number of teeth advisable are :—

Silent	15 and 90
Roller	8 ,, 70
Block	6 ,, 60

The distance between the sprocket centres should not be less than 1½ times the diameter of the large sprocket or greater than from 10ft. to 12ft. for heavier drives. With equal wheels it is a simple matter to reckon the number of pitches in a chain. The following formula is for unequal wheels :

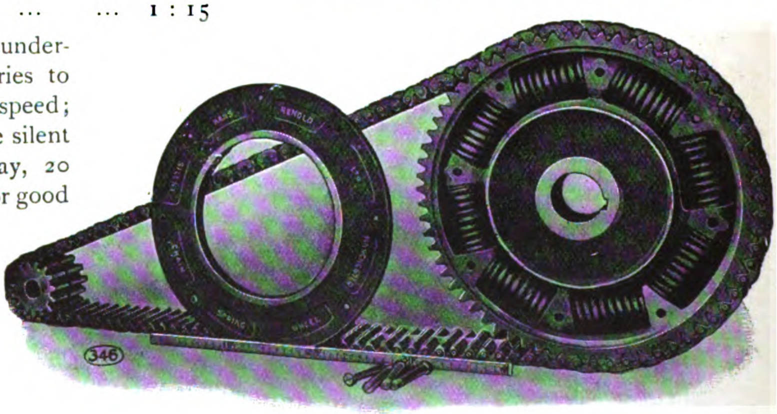


FIG. 5. SPROCKET WITH COVER OFF.

$$2C + \frac{N}{2} + \frac{n}{2} + \frac{\left(\frac{N-n}{2\pi}\right)^2}{C}$$

= chain length in pitches.

C = centre distance in pitches.

N = number of teeth in large wheel.

n = number of teeth in small wheel.

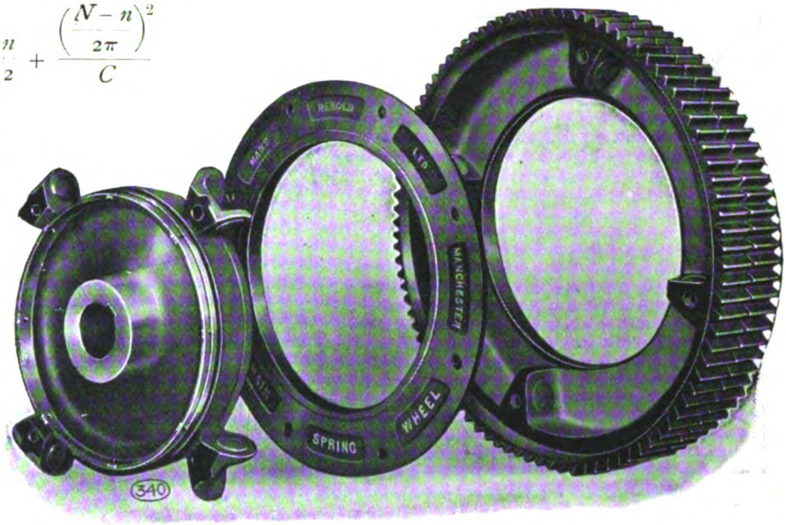


Fig. 6. The Three Parts of the Sprocket.

The tooth form adopted by Messrs. Hans Renold, Ltd., for roller and block chains is based on the geometrical line construction with pitch and chain parts as the basis. The tooth gap is then modified to give a little clearance for the block or roller, and the diameter of the driven wheel is enlarged slightly beyond the "theoretical diameter." These modifications allow for the wear of the chain and ensure the best average drive throughout its life.

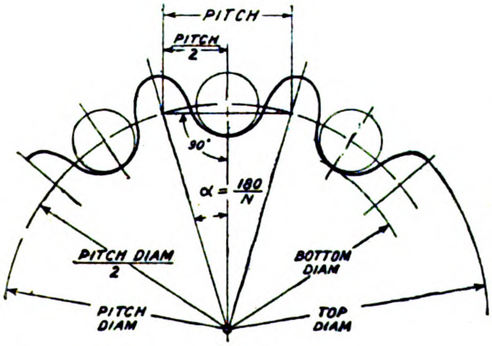


Fig. 7.

The following are the formulæ for obtaining the wheel diameters, Fig 7 :—

N = number of teeth. $\frac{180}{N} = a.$

$$\frac{\frac{\text{Pitch}}{2}}{\frac{\text{Pitch diam.}}{2}} = Sin\ a.$$

$$\text{Pitch diam.} = \frac{\text{Pitch}}{Sin\ a} = Cosec\ a \times \text{Pitch.}$$

Bottom diam. = pitch diam. − roller diam. (For driven wheel.)

Top diameter = addition to pitch diam. measured from enlarged drawing of tooth form.

Bottom diameter of driver wheel is made slightly greater than that of the driven wheel.

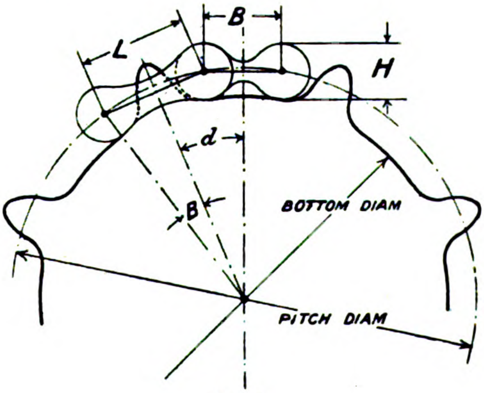


Fig. 8.

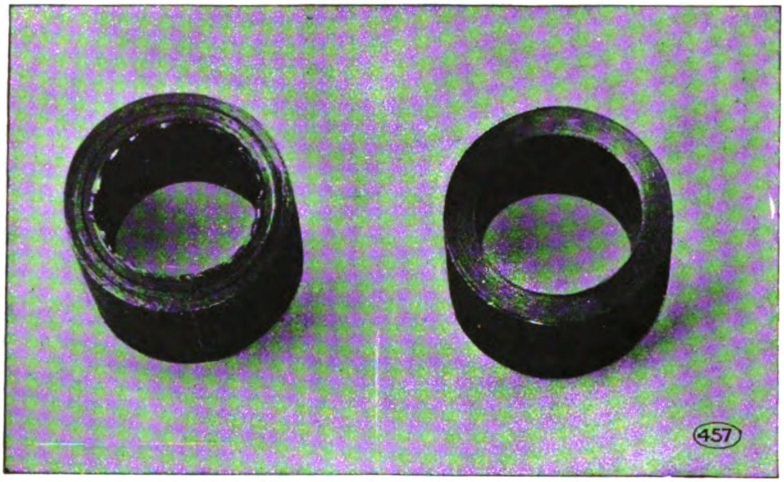


Fig. 9.

By Belt Machine. By Chain Machine.

This is to allow for chain stretching so as to obtain the best average drive throughout the life of the chain.

The differences between the tabulated "*R*" and "*N*" diameters have been found by experiment to give the best results.

N = number of teeth.
H = block head. (Fig. 8)
B = block pitch.
= drilling pitch + (drilled hole size − stud diam.).
L = link pitch.
P^1 = pitch diam.

Bottom diam. = $P^1 - H$ for driven wheel.
= $P^1 - H + C$ for driver wheel (C varying with wear expected, &c.).

Top diam. = P^1 + amount measured from enlarged drawing of tooth form.

$$a = \frac{180^\circ}{N}$$

$$Tan\ \beta = \frac{Sin\ a}{\frac{B}{L} + Cos\ a}$$

$$P^1 = \frac{L}{Sin\ \beta}$$

The pitch of "Renold" silent chain wheels is approximately at the top of the teeth. This type of chain resembles the roller in having one joint per pitch, and the diameters of its sprockets are obtained in the same way. (Fig. 10.)

$$\frac{\frac{P}{2}}{\frac{D}{2}} = \frac{P}{D} = Sin\ \frac{180}{N}$$

$$D = \frac{P}{Sin\ \frac{180}{N}} = P \times Cosec\ \frac{180}{N}$$

$A = D \pm 2U$.
U = the + or − difference between pitch diam. and top diam.
N = number of teeth.
P = chain pitch.

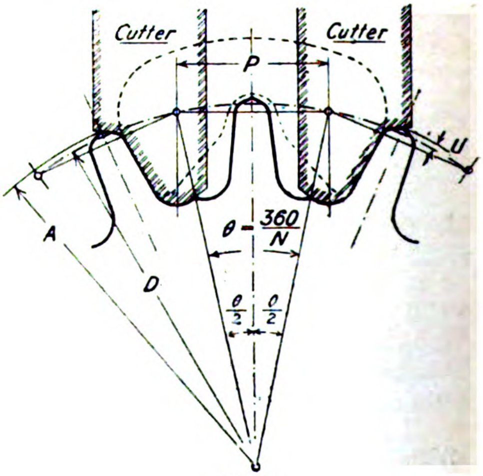


Fig. 10.

D = pitch diam.
A = top diam.

$$\theta = \frac{360}{N} \quad \frac{\theta}{2} = \frac{180}{N}$$

For any number of teeth the difference "U" depends directly upon the pitch diameter and the cutter position in relation to the setting gauge. This difference was obtained graphically from a tooth construction based upon the highest and lowest numbers of teeth cut by each cutter and the form of same.

As compared with belt driving, chain driving possesses considerable advantages, especially when applied to machine tools. A series of experiments have recently been carried out which prove conclusively that chain driving is far superior for such class of machines. In the first place it has been found through records of production extending over two years that the output is increased by over 20 per cent. During a specific trial lasting 138 hours there were obtained from:

A chain-driven machine 3074 rollers.

A belt-driven machine 2485 rollers.

Difference of output 589 rollers, or 23½ per cent. in favour of the chain-driven machine.

The work done was found to be superior on the chain-driven machine. The illustration Fig. 9 shows this clearly. It will be noticed that the cutting-off on the chain machine shows a smooth, steady action, the tool doing its appointed work unflinchingly at every part of the revolving rod—no more, no less. The cutting-off on the belt machine is entirely different. The surface looks torn rather than cut.

Only 25 per cent. of drill length was employed on the chain-driven machine.

The length of drill used in the 138 hours trial was:—

	Inches.	Per cent.
On the belt machine ...	6	100
,, ,, chain ,, ...	1⅜	23

The drilling was done at the following speeds:

	Speed at circumference of ¾in. drill.	Feed per rev.
Belt machine	93.75ft.	.0028in.
Chain machine	56.25ft.	.0046in

It was proved that one operator could attend to six chain-driven machines as against two belt-driven, this being in the main due to the fact that less grinding was requisite for the chain-driven machines than for the belt driven.

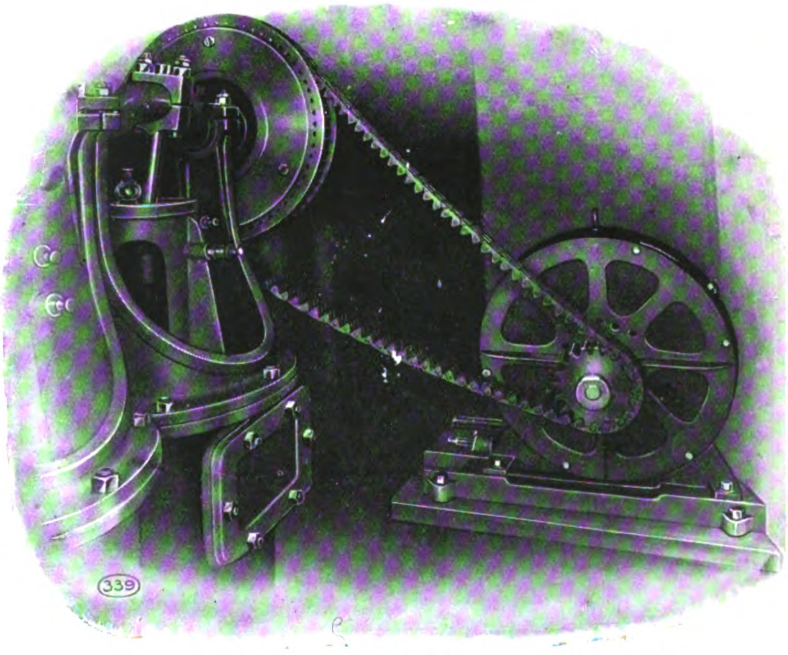


Fig. 11. Three-throw Pump, with Spring-wheel Chain Drive.

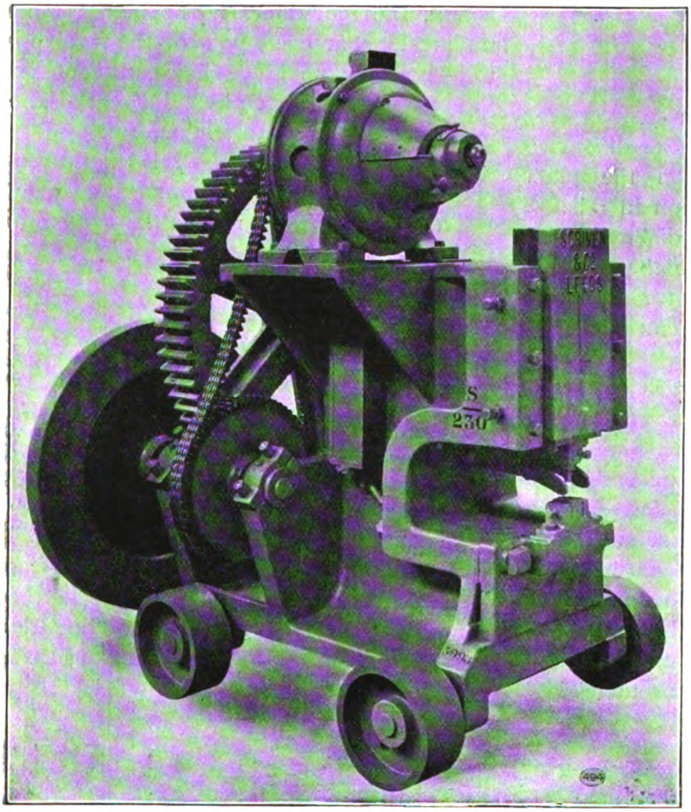


FIG. 12. LARGE PORTABLE PUNCHING MACHINE. MESSRS. SCRIVEN & CO., LEEDS.

Other advantages shown were that the wear and tear of the spindle and countershaft bearings is considerably reduced, and the alignment of the spindle and the turret head left undisturbed when chain driving was employed. Larger and heavier work than is possible on belt machines can be done very satisfactorily on chain machines; the power to drive is 20 per cent. less, although the production is fully 20 per cent. higher than on the belt-driven machine.

As already stated, chain drives are being largely adopted in all branches of industry. The following particulars and illustrations of different types of drive will probably be found interesting.

Calendering machines are frequently driven by silent chains from the jackshaft to clutch sprockets, there being many examples of the five-roller type and six-roller type driven in this manner. It is particularly desirable that calendering machines should be run steadily and uniformly to produce the best effect upon the face of the fabric, and it would appear that chain driving is extremely suitable for the purpose. The pitch of the chains employed is 1.75in., width 6in., speed 1230ft. per minute, power per calender 90h.p.

In Fig. 11 a spring wheel drive on a three-throw Edwards air-pump is shown. A spring sprocket is used for drives of this character where the load is pulsating. Powerful springs, acting under compression between the sprocket boss and the rim, absorb irregularities of load. The chain is therefore protected from the pulsations which have a tendency to shake it to pieces, and the armature of the electric motor also benefits materially. If the springs are properly adjusted, the chain runs quite smoothly.

In Fig. 12 a large portable punching machine is shown. As will be seen, the machine is driven by a silent chain from an electric motor to the second motion shaft, which is provided with a large and heavy fly wheel.

In Fig. 13 a lineshaft driven from an electric motor fixed on brackets in the wall in a more or less confined space or corner is shown. It is to be noticed that the large sprockets are usually placed above the small ones. This is a favourable condition, as the weight of the chain hangs on the large sprocket, and the chain and small wheel last appreciably longer.

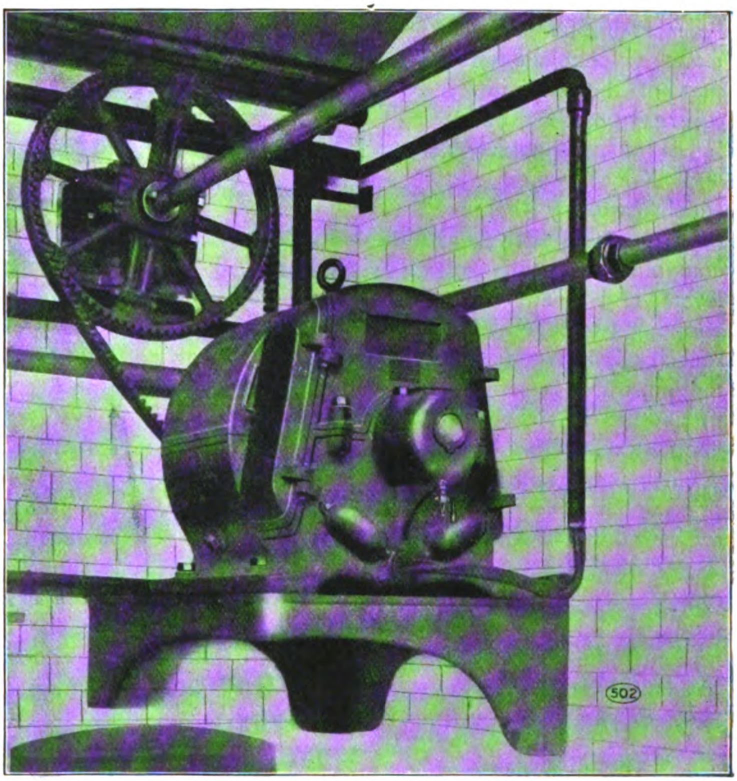


FIG. 13. EXAMPLE OF LINE-SHAFT DRIVING.

A special type of chain has been devised for employment in connection with carding engines. In Fig. 14, below, a carding engine with the chain applied is shown. Two chains of the same length and exactly equal in pitch are employed to carry the revolving flats. It is highly essential that such flats should move forward regularly and uniformly to produce good carding. The chains employed are joined up endless and the ends of the flats or rods are fitted by screws to the hollow bushes in the chains in such a way as to form a continuous lattice. The purpose of the flats, which are covered with wire teeth or clothing, is to card or comb the cotton fibres as they pass between them on the surface of the cylinder.

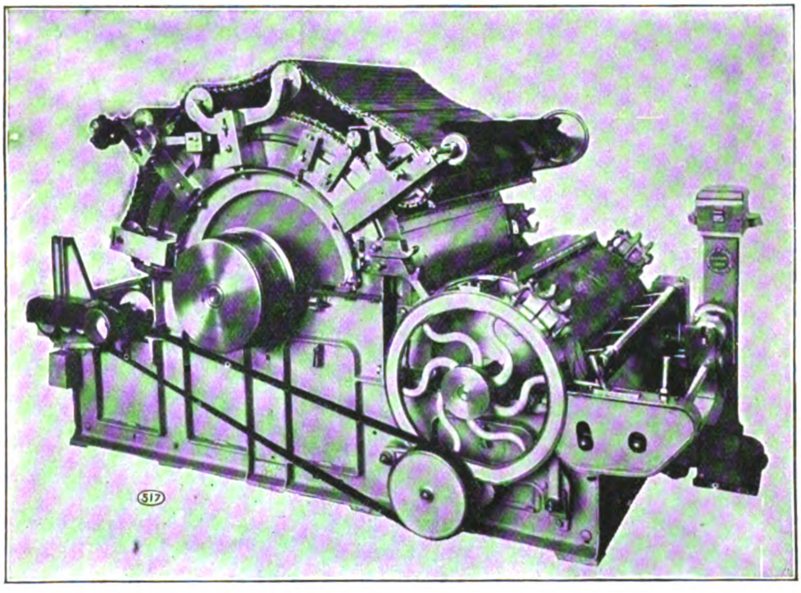


FIG. 14. REVOLVING FLAT CARDING ENGINE. MESSRS. DOBSON & BARLOW, LTD.

In the heavier types of looms chains should

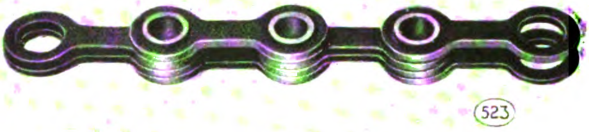


Fig. 15. Hollow Centre or "Flat" Chain.

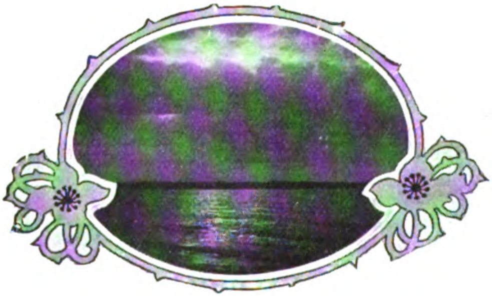
be most useful. For instance a block chain forms part of the motion for operating the shuttle boxes of a Hutchinson and Knowles loom, in which case, by the use of the chain drive, a compound system of levers and connections is avoided. By adopting two lengths of chain, joined by a special link, is secured a reciprocating motion, which is transmitted from one shaft to another at right angles to it in a very simple way.

Chains are now being largely used on printing machines. They are employed in such machines for the following purposes:—

For driving the machines from electric motors, &c.; for obtaining reciprocating motions in the machines themselves; for replacing the cross shaft and two pairs of bevels where one shaft has to be driven from another parallel to it (this is done very simply by mounting sprockets on the shafts and connecting them by a chain); as carriers and feeders: Chains for this purpose in particular demand very fine and accurate workmanship.

Enough has been shown to prove the claims made for chain driving. Its efficiency is certain, its durability has been sufficiently proved to warrant its considerable employment. It can be employed in nearly every case in which belts are now used, and with considerably better results. Undoubtedly we shall see considerable increase in chain driving in the near future.

Frank Nasmith.



IMPROVED STERN FRAME.

A PATENT has been taken out recently by Mr. Arthur A. Fownes, the managing director of the Fownes Forge and Engineering Company, Limited, of Tyne Dock, relating to the building of a weldless stern frame for iron and steel ships. The originality of this novel design lies in the fact that the stern frame is built together without any weld in its construction. It is forged in three separate pieces, and their arrangement is shown in the line drawing, Fig. 2. There is a scarph joint below the boss, and above at the archway instead of the ordinary weld, the back post is turned truly circular in the lathe from a point just below the arch, and the circular section extends right down to its base. It has no weld in the back post, and the base is shrunk into the bottom piece heel. The gudgeons are all machined and are portable, and in addition to being keyed they are shrunk on to the circular back post.

This patent stern frame offers very valuable facilities for rapid repair. In the event of damage a new bottom piece, which is usually the first to suffer under such circumstances, can be fitted under the Fownes' patent without it being necessary to cut the entire stern frame out of the ship and send it to the forge. In a similar manner the back post or any of the portable

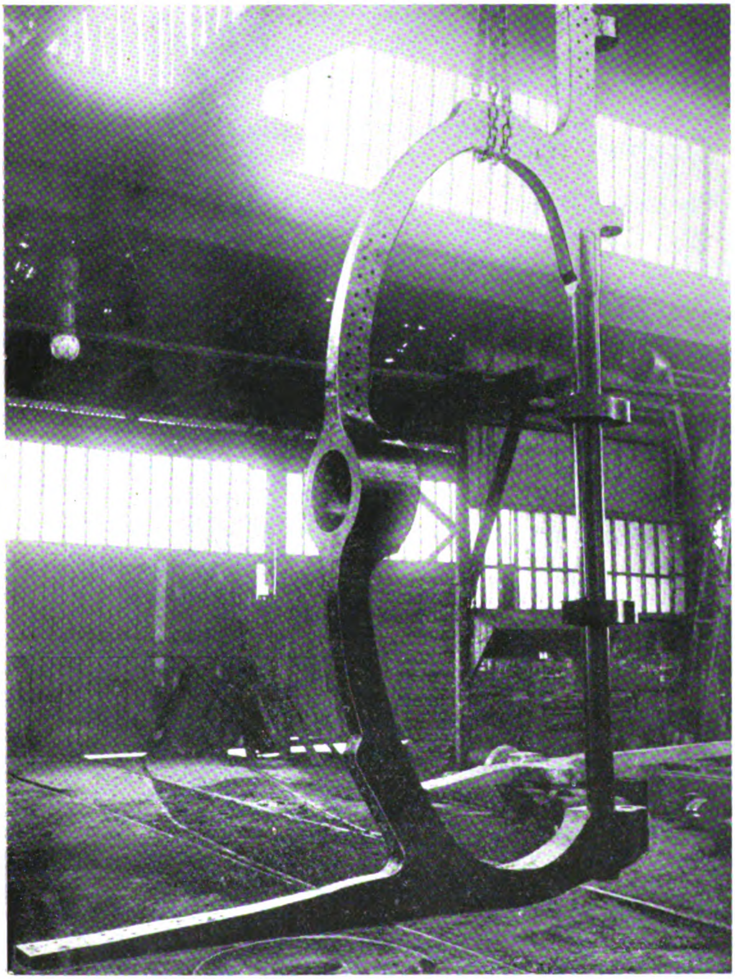


FIG. 1. GENERAL VIEW OF THE FOWNES STERN FRAME

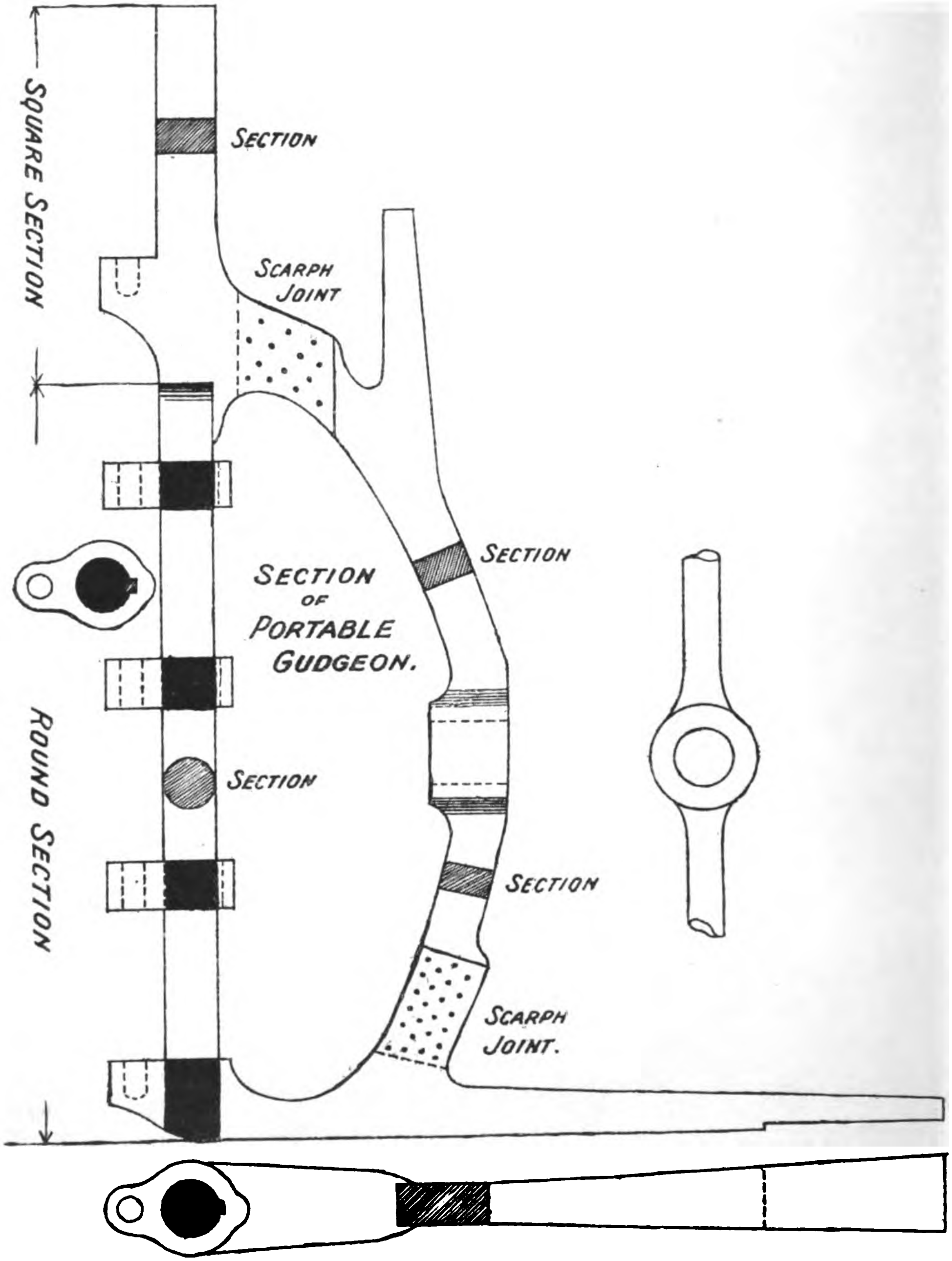


FIG. 2. THE FOWNES STERN FRAME. ALL SHRUNK JOINTS SHOWN BLACK.

gudgeons may be displaced without disturbing the boss piece in the vessel. There is also the consideration, which is the main object of the design, that the entire frame can be much more expeditiously manufactured than the older type, because the various parts can be distributed simultaneously during the course of manufacture over the necessary machines. It therefore follows that the important features of cheap production, namely continuity of machine work on the parts, can be maintained until they are finally completed for building together.

Mr. Fownes introduces by his patent the method of shrinkage in stern frame building as against the older and rather slower method of welding ; the object, therefore, of the design is to supply an important article of marine manufacture possessing the required stability to withstand the great strain which forgings are put to in our large ships of to-day, whilst entirely complying with that ever-increasing modern demand in the direction of rapid dispatch. That this object has been attained may be shown by the fact that the design has been approved by the various classification societies under which forgings for marine use are made.

Fig. 1 illustrates the first stern frame which was made under this patent, and which was the object of inspection by a considerable number of gentlemen interested in shipbuilding and marine architecture, in a visit some few months ago to the Fownes Forge. The originality of the design attracted considerable attention and interest, and it was generally felt not only that quite a new departure had been made in the method of stern frame building, but also that the Fownes patent would considerably affect the methods of ship repair of the future.

◆

Floating Electric Charging Plant.

ALTHOUGH electricity has several decided advantages as a power for launches and yachts, such as entire freedom from danger of fire or explosion and absence of noise, heat, vibration, smoke and foul odour, it is subject to the limitation that any long-distance cruising is impracticable unless charging facilities can be found at intervals along the route.

With a view to overcoming this objection, an electric charging launch has been introduced. The first vessel of this kind is now afloat and it is expected that it will solve the question of the use of electricity in large yachts, since it can be operated at full power for 100 hours on one filling of the petrol tank, thus enabling the yacht to make a trip of 2000 miles before either craft would have to enter port. With the recharging launch as an auxiliary, the yacht is not dependent upon electricity ashore for charging her batteries. The power launch is 35ft. long, 9ft. beam and 2ft. draught. The steering wheel is located on the after deck, together with engine control devices which enable one man to steer the boat and manage the engine. The electric power equipment consists of a 40h.p., six-cylinder petrol engine, with mechanical reversing gear connected to the propeller shaft. A 30kw. dynamo is direct connected to the crankshaft at the forward end of the engine. A slate switchboard is fixed on the port side of the cabin, with the necessary instruments and switches for connecting the dynamo with the batteries of the electric yacht. The dynamo is so arranged that current can be generated while the boat is lying at anchor or when under way. The plant has sufficient capacity for recharging the yacht's batteries in three or four hours. The charging launch has a speed under her petrol engine power of nine miles an hour and carries 400 gall. of fuel, on which she can be operated for 100 hours and recharge the yacht ten or twelve times. On one charge of her batteries the yacht can run 200 miles, and in connection with the auxiliary launch her radius is unlimited.

HOW HOT WATER ASSISTS FIRE.

It seems almost paradoxical that the most largely used agent for quenching a fire is made up of two elements either of which will burn vigorously in an atmosphere composed of the other. The ancients of European history believed that water and fire were in themselves two elements utterly opposed to one another; the former was used to extinguish the latter, and the latter was able to dissipate the former. It was not until comparatively recent years that the fact was recognised that water could, under certain conditions, be utilised to assist the production of flame, or, to put the matter in modern parlance, that it could be dissociated into its elementary constituents in order to maintain and augment combustion.

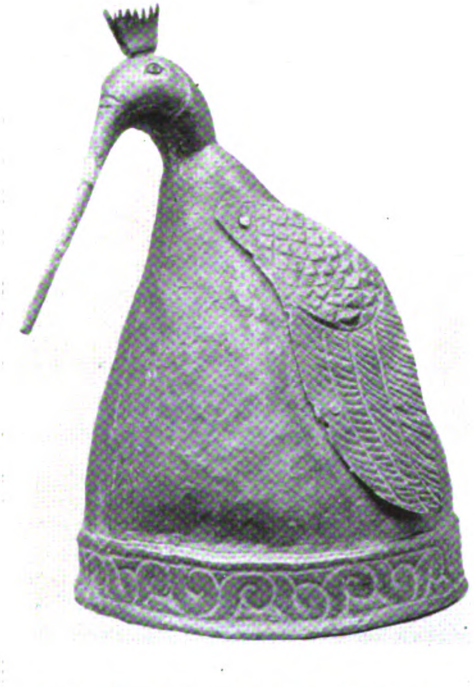


Fig. 1. Native Thibetan Steam Fire-blower.

Nevertheless, to other races of mankind this somewhat uncommon use of steam has been known for quite a long time. The first illustration comes from a land which was till quite recently unknown. Until Sven Hedin and Younghusband had opened up the interior of Thibet we were in utter ignorance of the degree of civilisation of its inhabitants, and now that the secrets of the land of the Lama are being revealed we are astonished at the evidences of ancient civilisation which are being discovered. The illustration of an ingenious method of blowing a fire shows that the Thibetans have long had a knowledge at any rate of one use of steam. The vessel shown, which is 15¼in. in circumference at the base, 8in. in height, and 4¼in. from the tip to the crest of the spout, and which has no other aperture than the beak of the bird represented, is first heated by placing it near to the fire in order to expand the air within

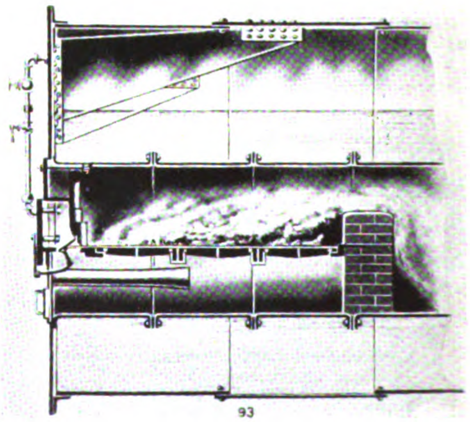


Fig. 2. The Meldrum Steam Blower.

it and expel a large proportion. The spout is then dipped under the surface of water, and as the air cools and contracts, the water is drawn into the interior. When the blower is required, it is placed on the newly kindled or nearly extinguished fire of cow-dung or yak-dung. Steam is soon generated, and coming out of the spout in the form of a jet it quickly blows up the fire to brisk incandescence. The vessel illustrated, which is exceptionally ornamental and of the standard used by the Thibetans of large influence or wealth, is made from an alloy consisting chiefly of copper. The particular example shown happens to be in the shape of a bird, but the forms taken by this article range over a wide variety of shapes. The average poorer Thibetan carries a much smaller and plainer article, and in his journeys he often carries some of his fuel in a state of smouldering combustion in a metal pot, only the application of the blower being needed at any time to raise a fire.

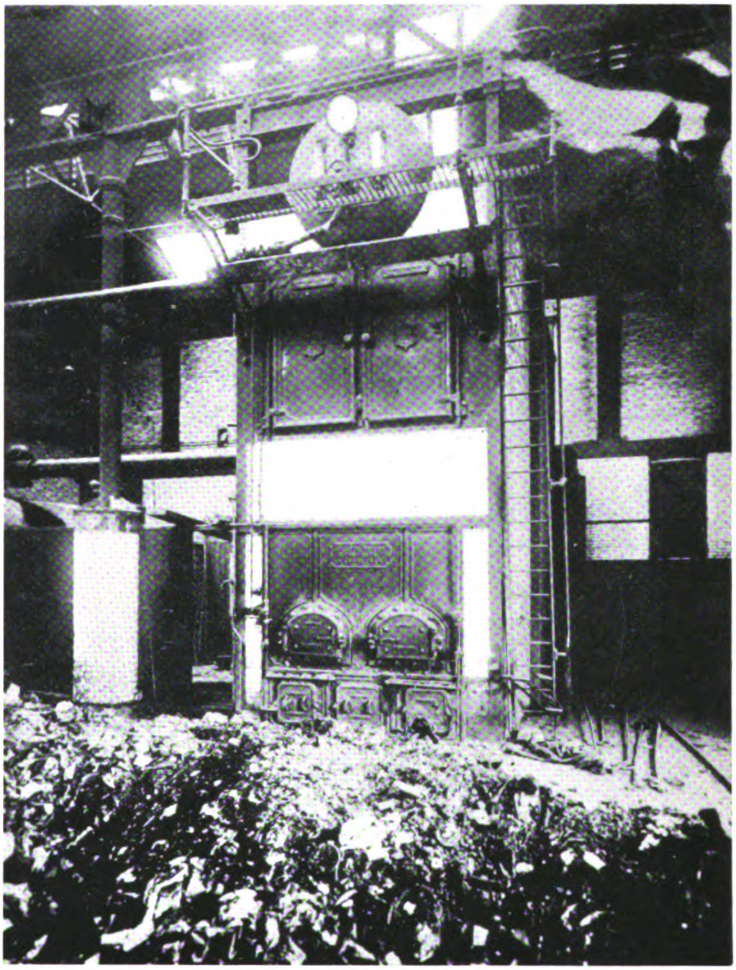


FIG. 3. REFUSE DESTRUCTORS.

It remained, however, to the nineteenth century to develop this principle into scientific accuracy, and we are indebted to the scientific researches of Korting, a Scandinavian, and Meldrum, an Englishman, for the application of jets of steam for forcing the operations of boiler fires. The second illustration shows the way in which Meldrum accomplished his solution of the difficulty. It represents a section through the front part of an ordinary Lancashire boiler such as is used in any of our factories. Instead of having the grate open to free air below the fire bars, however, a long nozzle, something like a blunderbus, projects inwards. At the narrow end of the tube, at its centre, a fine jet of steam shoots along the bore. All round this jet is an opening to the air outside the boiler, and the rush of steam along the tube creates a sucking action on the air, causing the air and steam to fly forward and upward through the grate together. The steam is decomposed by the heat of the fire into its constituent elements, oxygen and hydrogen, which burn; and the air carried along with the steam forms a huge blast which whips up the fire into strong energy. By means of such a blast the steaming powers of boilers can be tremendously augmented, and inferior fuels can be burnt at a very slight extra cost of energy in the form of steam diverted to the nozzles. For example, in the third illustration is a view of one of London's refuse destructor works, where one of these blowers is at work burning up the city refuse, and converting this waste product into useful steam for producing electricity. There are nowadays no less than thirteen thousand of these steam jet furnaces fitted in various parts of the world for the burning of all grades of fuels.

The Korting apparatus is another example of the application of this principle. In this case the blower is placed outside the boiler, and communicates with it by ducts of iron or brick work. But the idea is very much the same. At the centre of the back end of the blower there is a thin stream or needle of steam. Immediately surrounding this is a series of hollow cones with the points taken off, and the steam rushes through the holes thus made. Air is dragged in at the bases of the cones, and the whole volume of air and steam rushes through a trumpet to the duct. In the East and West Indies these blowers may be seen on boilers which are burning up the wet green sugarstalks or megass which are left after the sweet sap which ultimately becomes sugar has been crushed out of them.

Perhaps one of the most interesting examples of this device is in its application to improve bad chimney draughts. The width and height of a chimney may not be sufficient for the number and size of the boilers installed; dust and soot may accumulate and choke the passing away of the products of combustion; the temperature of the gases in the chimney may be too low, and they may move sluggishly; a hot summer's day or the wind at the top of the chimney may hinder the escape of smoke. Whatever may be the cause a chimney ventilator on Korting's principle overcomes bad draught and gives a quick fire and perfect combustion. They will be found fitted to marine boilers in the tropics, which have always a low chimney and bad draught, to the chimneys of chemical works which have to remove noxious gases; and in some temporary furnaces the chimney or funnel is entirely done away with and the steam jets relied upon to obtain the necessary suction of air through the fires.

It will be seen, therefore, that the apparent anomaly of using water to fan a fire has been well overcome in these days of advanced science, and another example added to that long list of devices which man's ingenuity has designed to overcome the disadvantages of natural operations.

VICTOR WHITE.

RELAY GOVERNOR FOR PELTON WHEELS.

The illustrations given are of a Pelton wheel, fitted with a Pitman patent hydraulic relay governor. The wheel operates under a head of 120ft., and with both nozzles in service generates 80b.h.p. The pipe line is 50 chains long, its diameter being 22in., and the velocity of flow through it about 3ft. per second. As will be seen (Fig. 1), the speed of the wheel is governed by moving deflectors into the path of the jets from the nozzles, thus diverting more or less of the total discharge direct into the tail-race. Both deflectors are operated simultaneously, being coupled to the cross-head of an hydraulic relay as shown. The coupling rod between the two jets is provided with a screw union having right and left handed threads, thus enabling the two deflectors to be accurately adjusted to act in unison. A plan of these deflectors is shown separately to an enlarged scale in Fig. 2. Details of the hydraulic governor are shown separately in Fig. 3. The hydraulic cylinder rests on planed seatings,

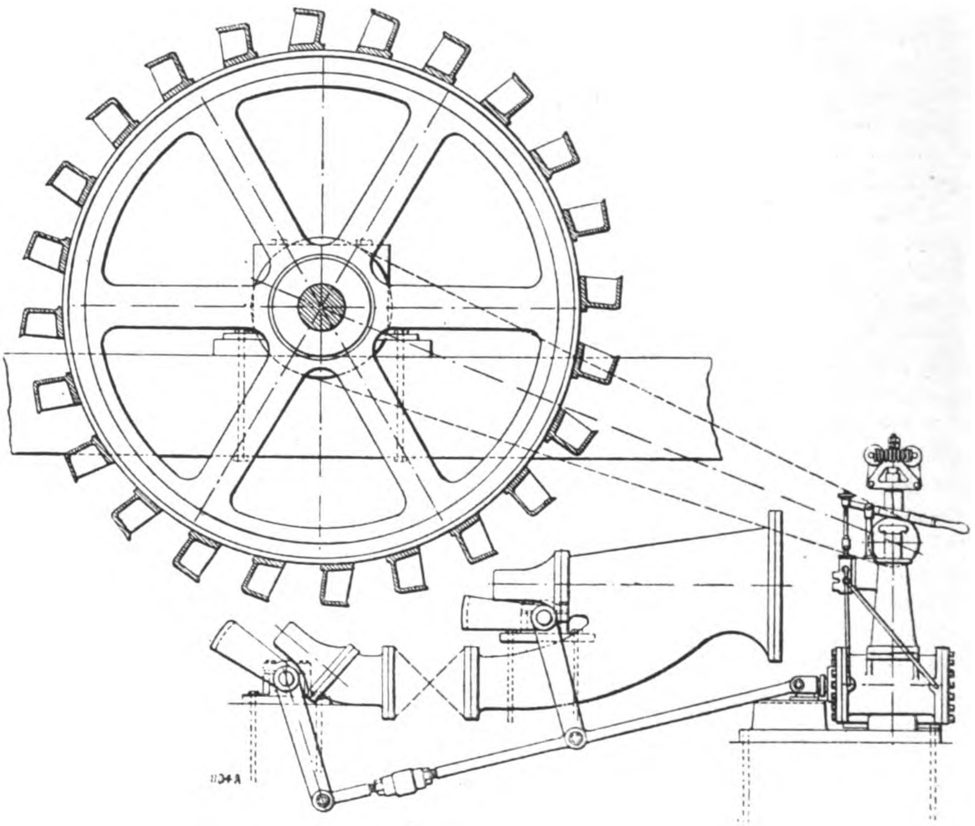


Fig. 1.

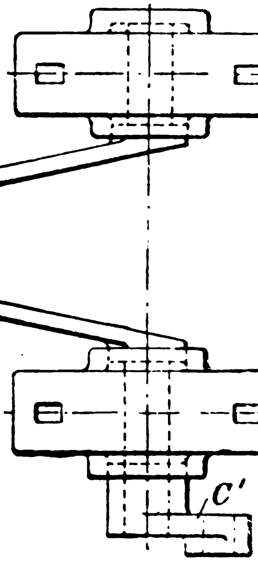


FIG. 2.

cast solid with the slide, over which the cross-head travels. The coupling rods between the latter and the deflectors are, it should be noted, always in tension, so that the cross-head is always pressed downwards when the deflectors are in the path of the jet. The hydraulic cylinder derives its supply of pressure water direct from the pipe-line through the valve-chest shown in position at F, Fig. 3, and separately alongside The inlet to this chest is at A, the water entering passing first through a strainer and then through a somewhat small nozzle, intended to ensure smoothness and regularity in the motion of the relay piston. The exhaust port is at B, and from D and C pipes lead, as shown, to opposite ends of the relay-cylinder. The admission of the pressure water to this clinder is controlled by a small piston valve of phosphor-bronze, marked E in the drawing. The valve chest is itself of delta metal.

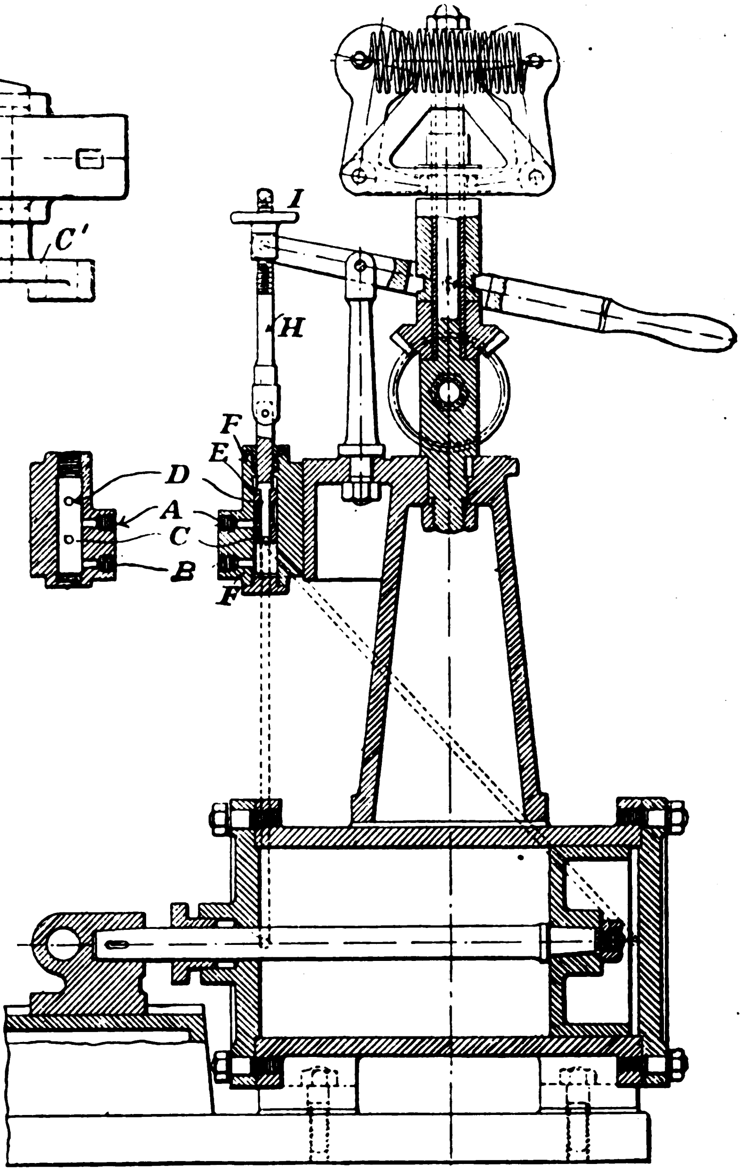


FIG. 3.

The position of the valve relatively to the governor-balls is adjustable by means of a screwed link and the lock-nut shown at I. The governor is operated by a belt drive and bevel gearing as indicated.

At normal speed water is shut off from both ends of the relay cylinder, but a change of speed in one direction or the other is followed by admitting water to the corresponding end of the relay cylinder, and thus moving the deflector in or out of the path of the jet. Under reasonable conditions of work the governor will maintain the speed constant within a limiting variation of three per cent., and the mean speed can be adjusted by hand through a considerable limit by lengthening or shortening the link H. For very close speed regulation, as in driving alternators, &c., with heavy load charges, a compensating or "overtailing" device is fitted, either mechanical or electrical. This governor is suitable for operating needle nozzles, rectangular nozzles, and the gates of turbines, &c.

Central Station Publicity.

THE current number of the Quarterly Bulletin issued by the West Ham Corporation Electricity Department maintains its high standard of effective advertisement and is worthy to rank amongst the best of its kind produced in this country. A forcible paragraph is as follows:—

The figures below indicate more than a mere preference for electricity to gas for lighting purposes on the part of the various tradesmen whose premises are located in the districts given below; they represent an overwhelming conviction in the minds of City shopkeepers as to which form of lighting is best suited for their requirements.

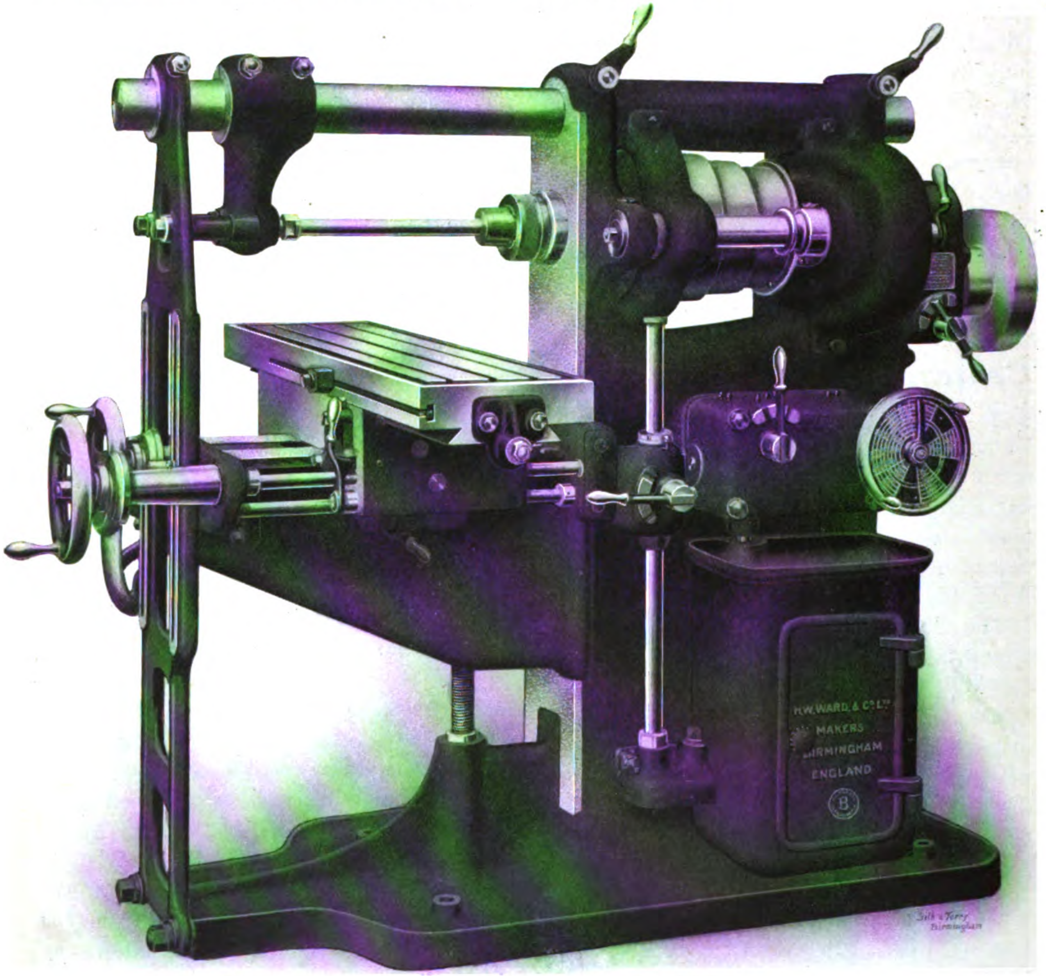
	Using the Electric Light.	Using Gas.
Cheapside (right-hand side going westward).	66 ...	5
Cheapside (left-hand side going westward).	62 ...	9
St. Paul's Churchyard (right-hand side going westward)	21 ...	3
Ludgate Hill (right-hand side going westward)	29 ...	2
Ludgate Hill (left-hand side going westward)	22 ...	6

Many of the electrically lighted premises mentioned in the above list consist of a number of shops occupied by the same firm: the said premises, however, have only been reckoned as single units. On the other hand, in practically every case where gas is being used the figures given represent the actual number of shops in question.

Milling Machine.

THE following page illustrates a machine recently introduced by H. W. Ward & Co., Ltd., for all kinds of general milling, and to meet the demand of those who require a high-class plain miller of rigid design. As will be seen, the headstock and bed are cast in one piece, with a substantial slide down the front, on which is fitted the knee bracket. The spindle is of steel, hardened and ground, and runs in conical gun-metal bearings. It has suitable and efficient arrangements for thrust and wear, and is driven by a three-speed cone pulley carrying a wide belt and two sets of double gearing. This, together with the two speeds on the countershaft, gives eighteen changes of speed to the spindle. For the convenience of fastening and removing the mandrils there is a hole right through the spindle, and a bar is supplied for forcing out the mandrils. The steady bar is of steel, and is securely held by two bolts and split grips. It can be readily adjusted as to position, and carries on its outer end a steady bracket for supporting the end of the mandril. The bush for this purpose has a parallel hole, in which runs the end of the mandril; this method allows the mandril to expand under heat from cutting without bending.

The bush is split and tapered on the outside so that it may be adjusted to take up wear. An effective steady brace is supplied to tie the cylindrical steady bar rigidly to the knee bracket and foot of the machine, thus reducing vibration to a minimum. The knee bracket slides on a vertical vee on which it has a long bearing surface. It may be lowered or raised by screw and bevel wheels, and is provided with an arrangement for locking securely in any position. The weight of the bracket and slides is taken on a ball-race, thus securing a very free vertical adjustment. The middle slide has a good bearing surface on the knee bracket, and a hand movement of 8½in. by handle and screw. The table is 4ft. long by 12in. wide over all, and has an oil or suds dish cast around it, and three tee slots planed in its surface for the convenience of securing work, vices, or jigs. It has both automatic and hand feeds. The automatic feed is reversible by the lever on the small box on the knee bracket, which operates a clutch between a set of reversing bevels. The feeds may be driven either from the spindle or from the countershaft. There are sixteen changes in all, ranging from .55 to 7.3 per minute.



28in. by 8½in. by 19in. Milling Machine.

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